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Iizuka et al.

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(54) **SOHC TYPE ENGINE**

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May 17, 2001 (JP) 2001-148511

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(52) **U.S. Cl.** **123/310**; 123/90.27; 123/308; 123/432

(58) **Field of Search** 123/90.27, 308, 123/310, 432

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(57) **ABSTRACT**

An SOHC-type engine in which first and second insertion/removal guide sections for guiding the insertion and removal of first and second spark plugs, respectively, are provided on a cylinder head including an intake valve and the first spark plug disposed therein and arranged along an axis of a camshaft, and an exhaust valve and the second spark plug disposed therein and arranged along the axis of the camshaft.

20 Claims, 13 Drawing Sheets

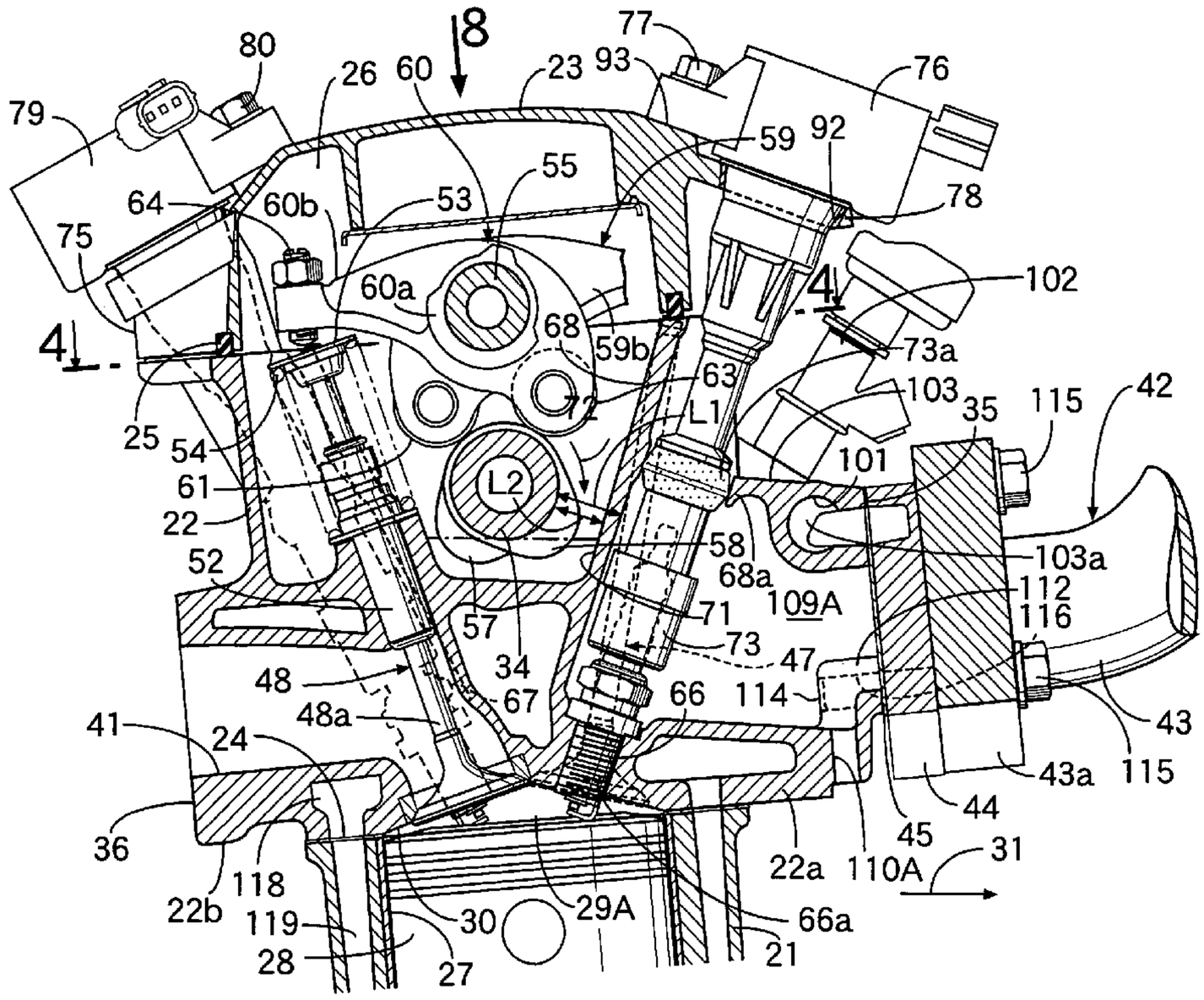

FIG.1

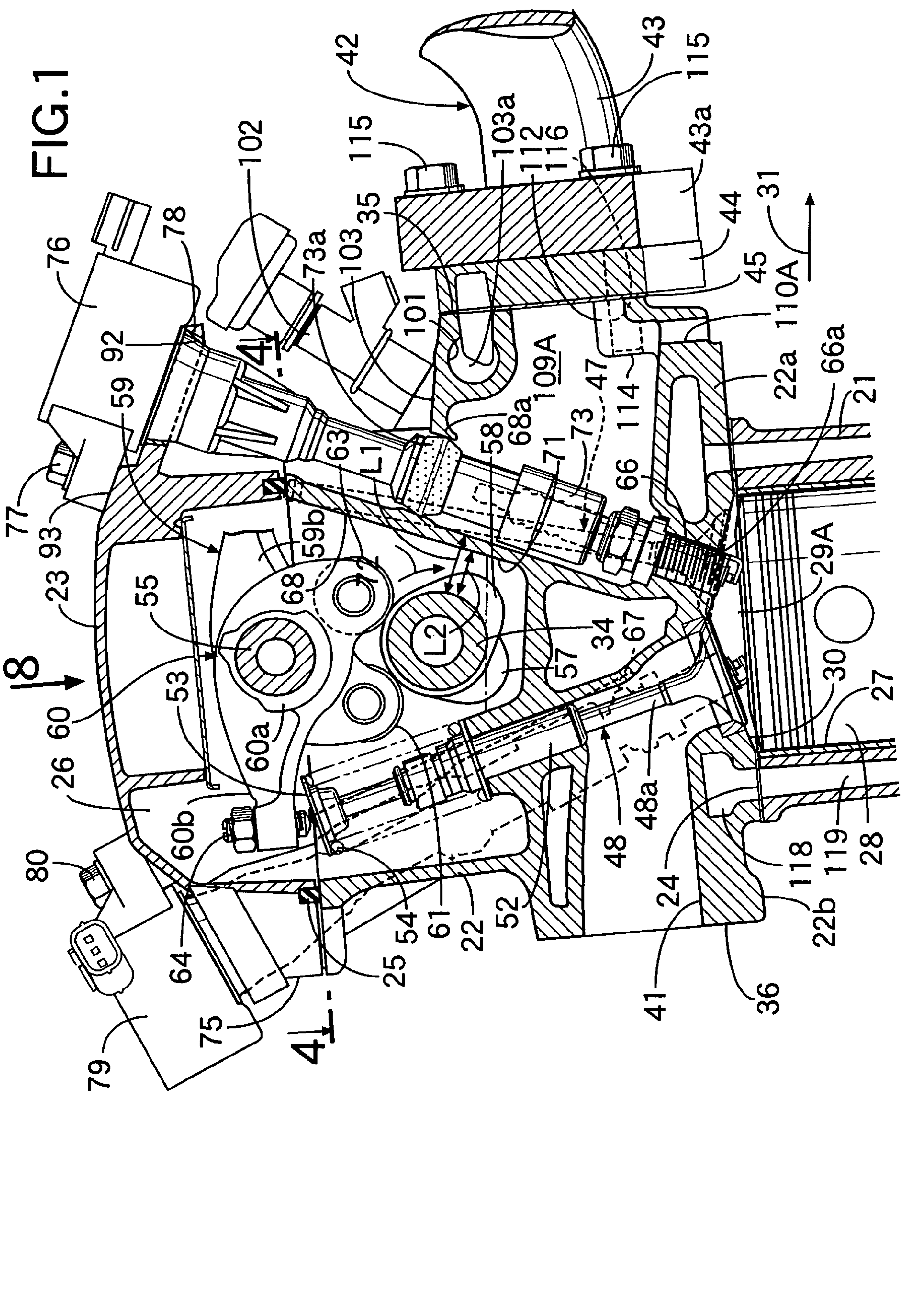
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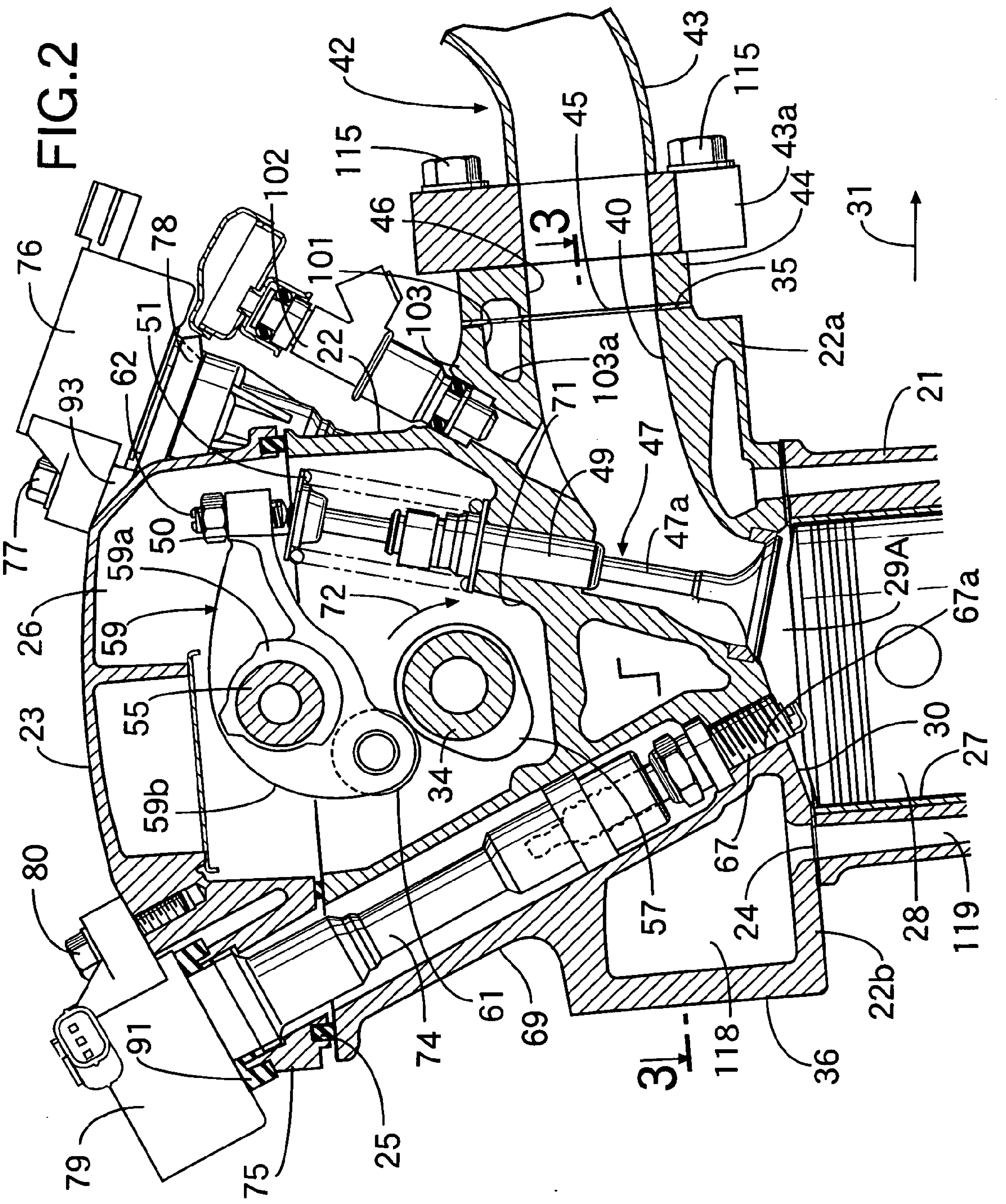
FIG.2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77
71
47
49
47a
29A
67a
50
59a
26
59
72
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23
34
30
27
59b
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22b
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FIG.3

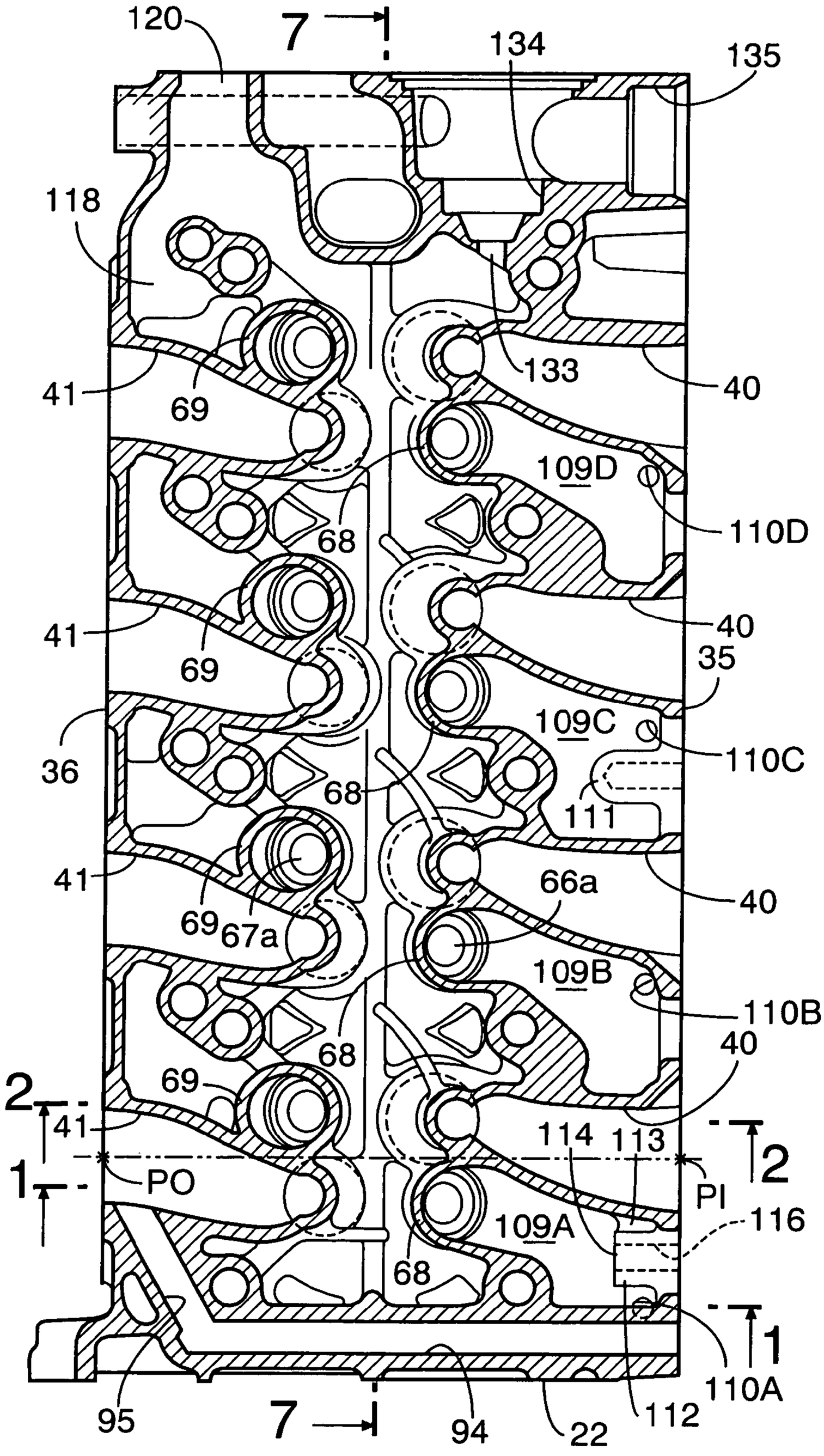
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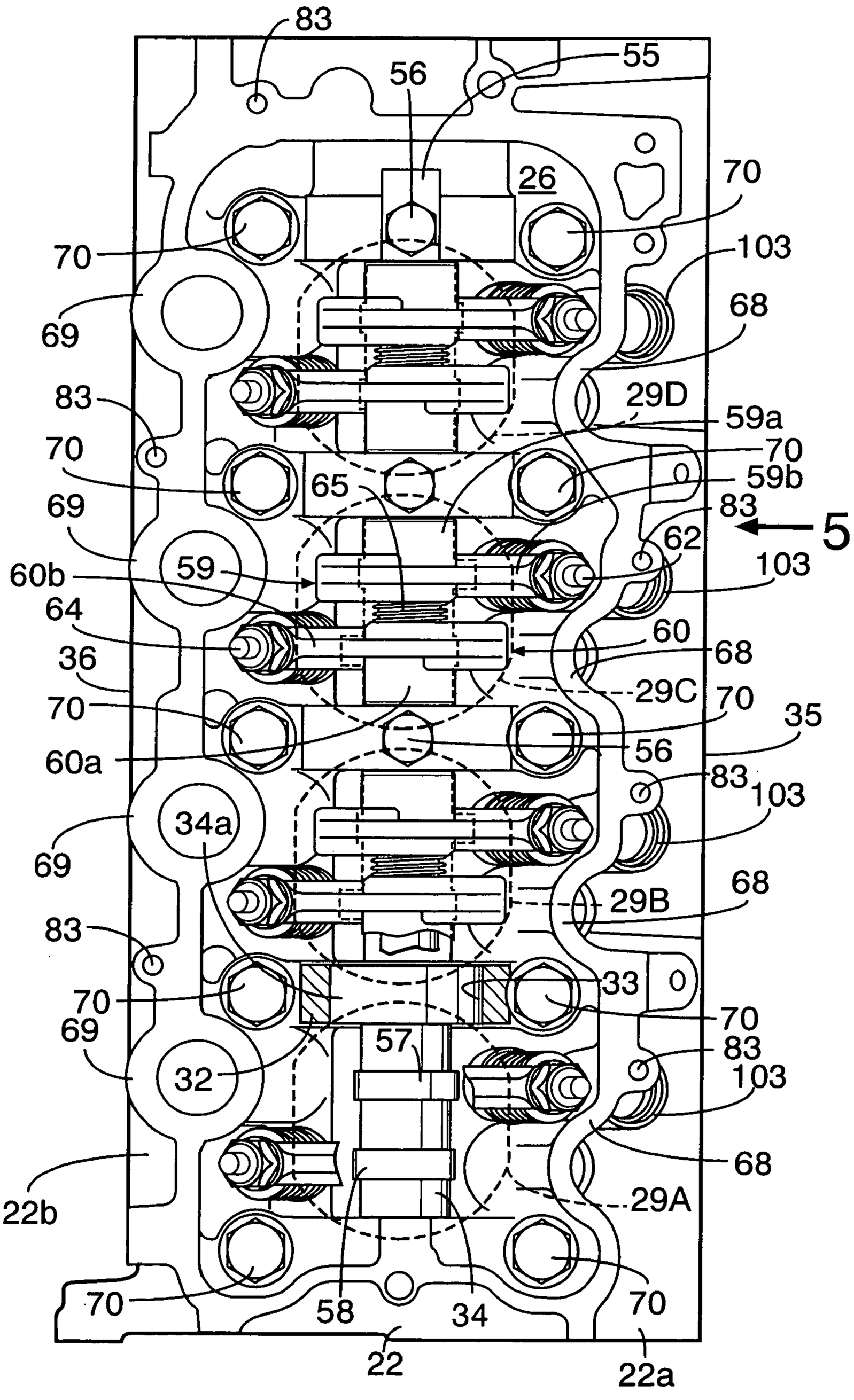
FIG.4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29C
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FIG.5

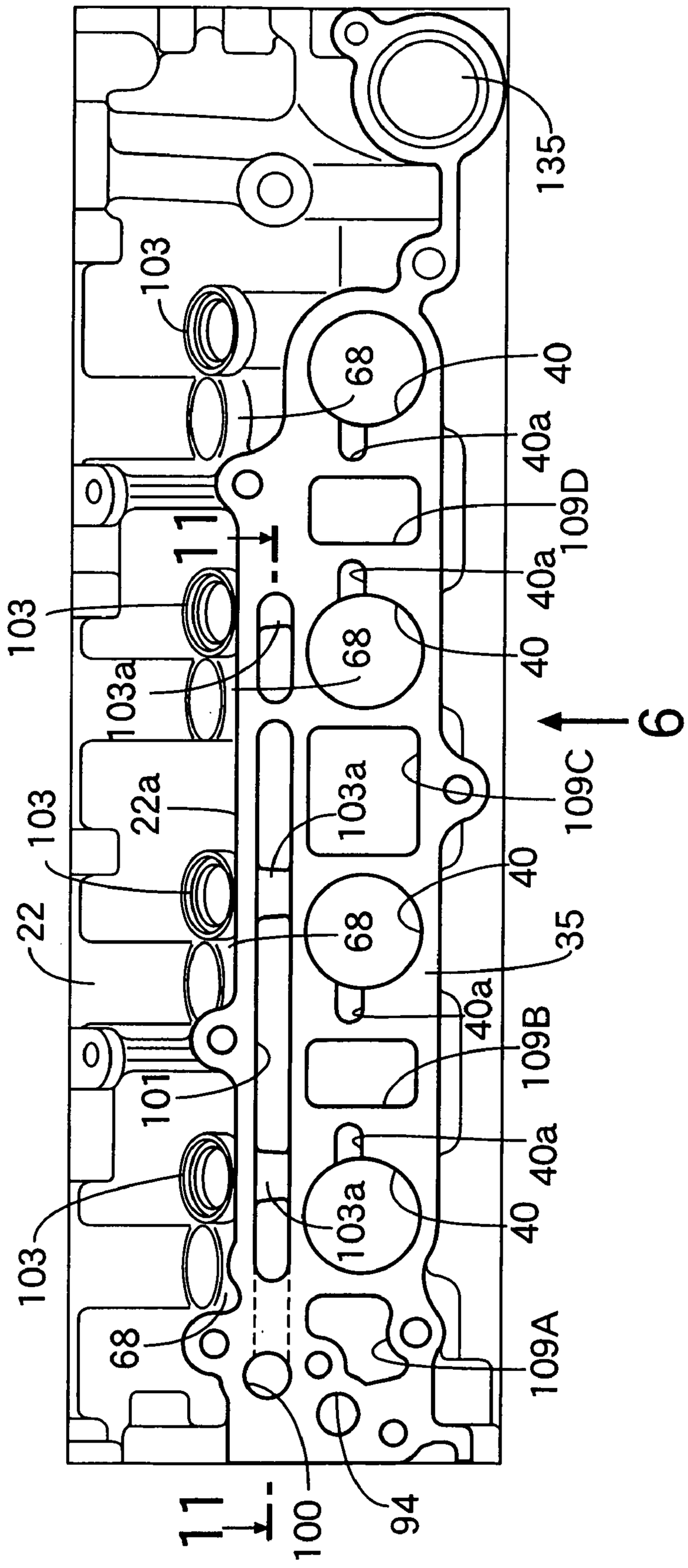
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FIG.6

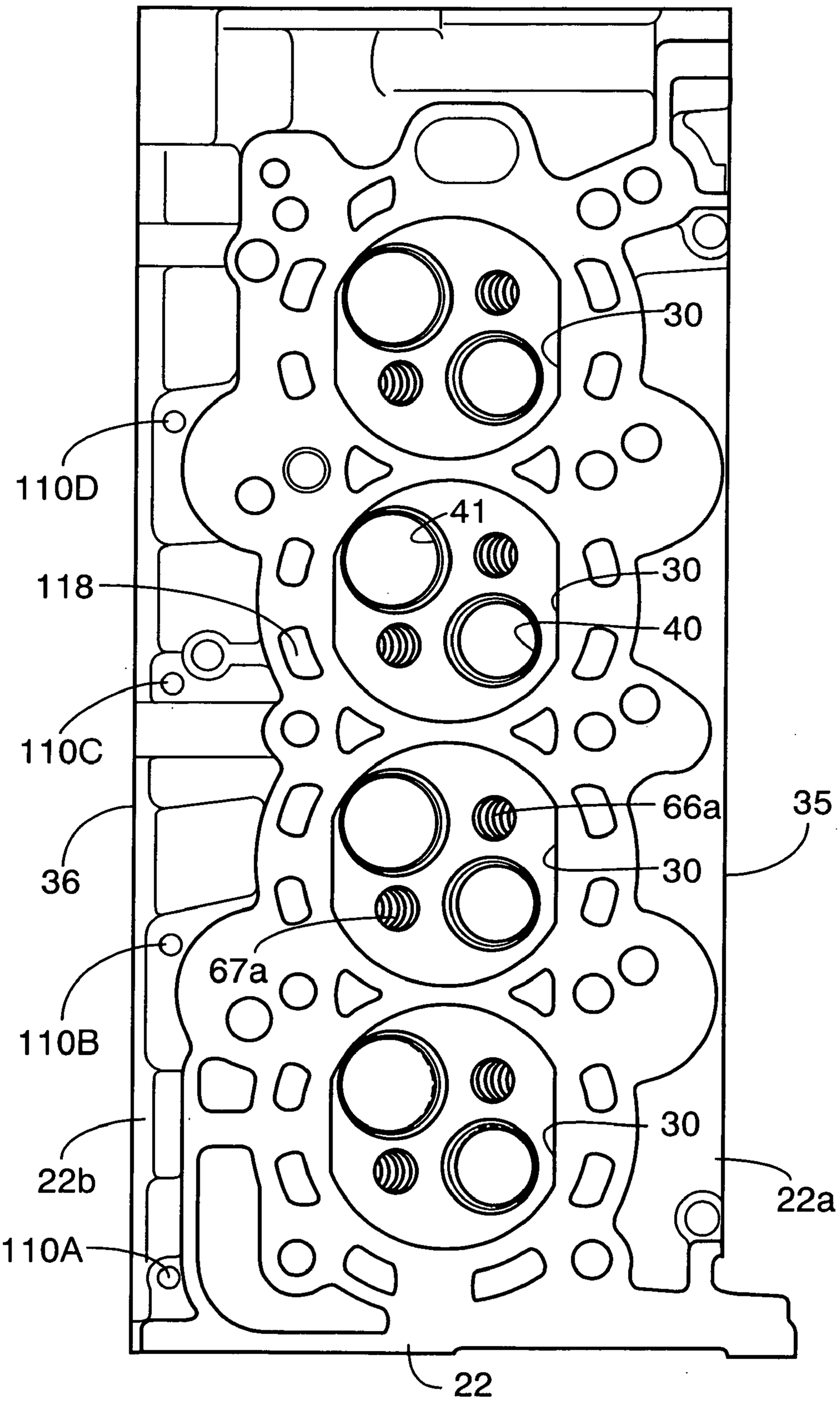
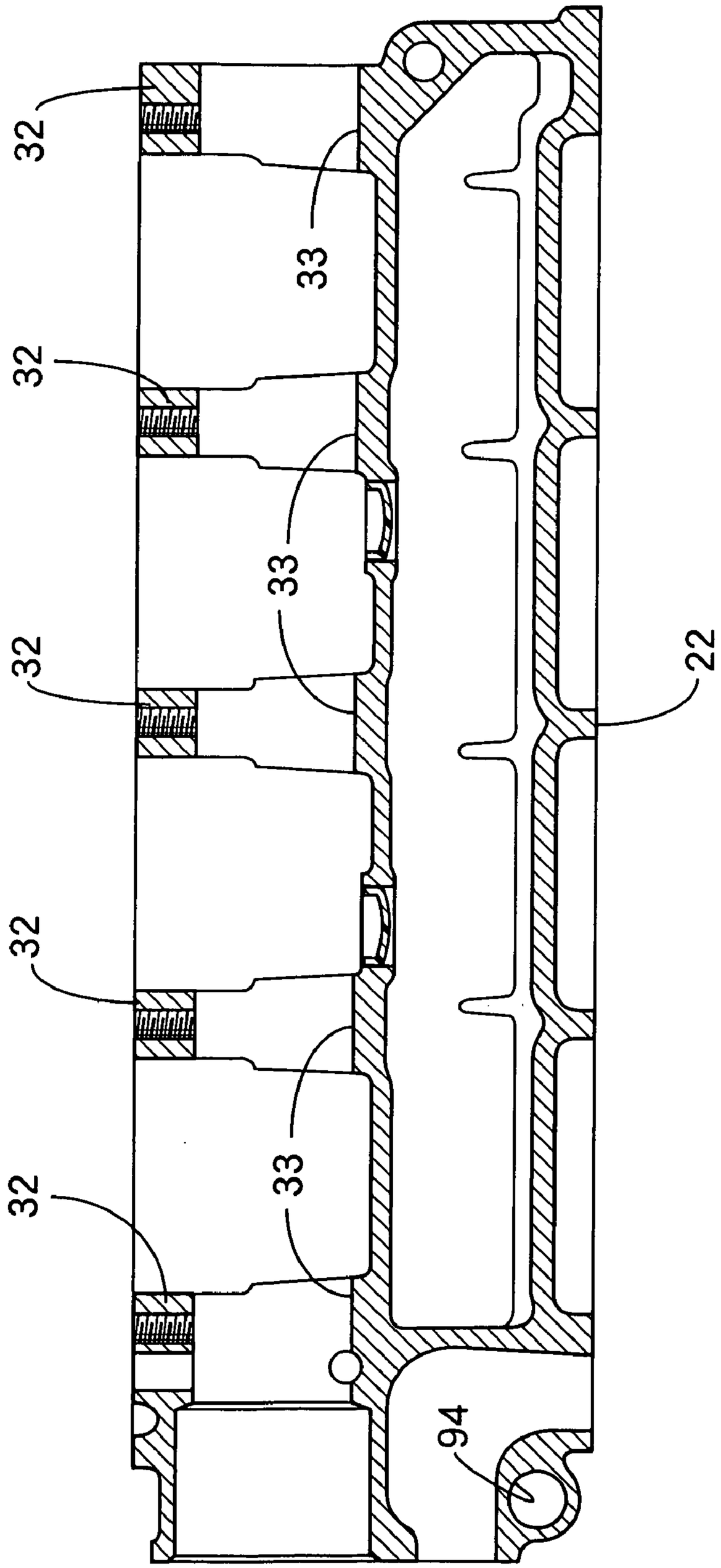


FIG.7



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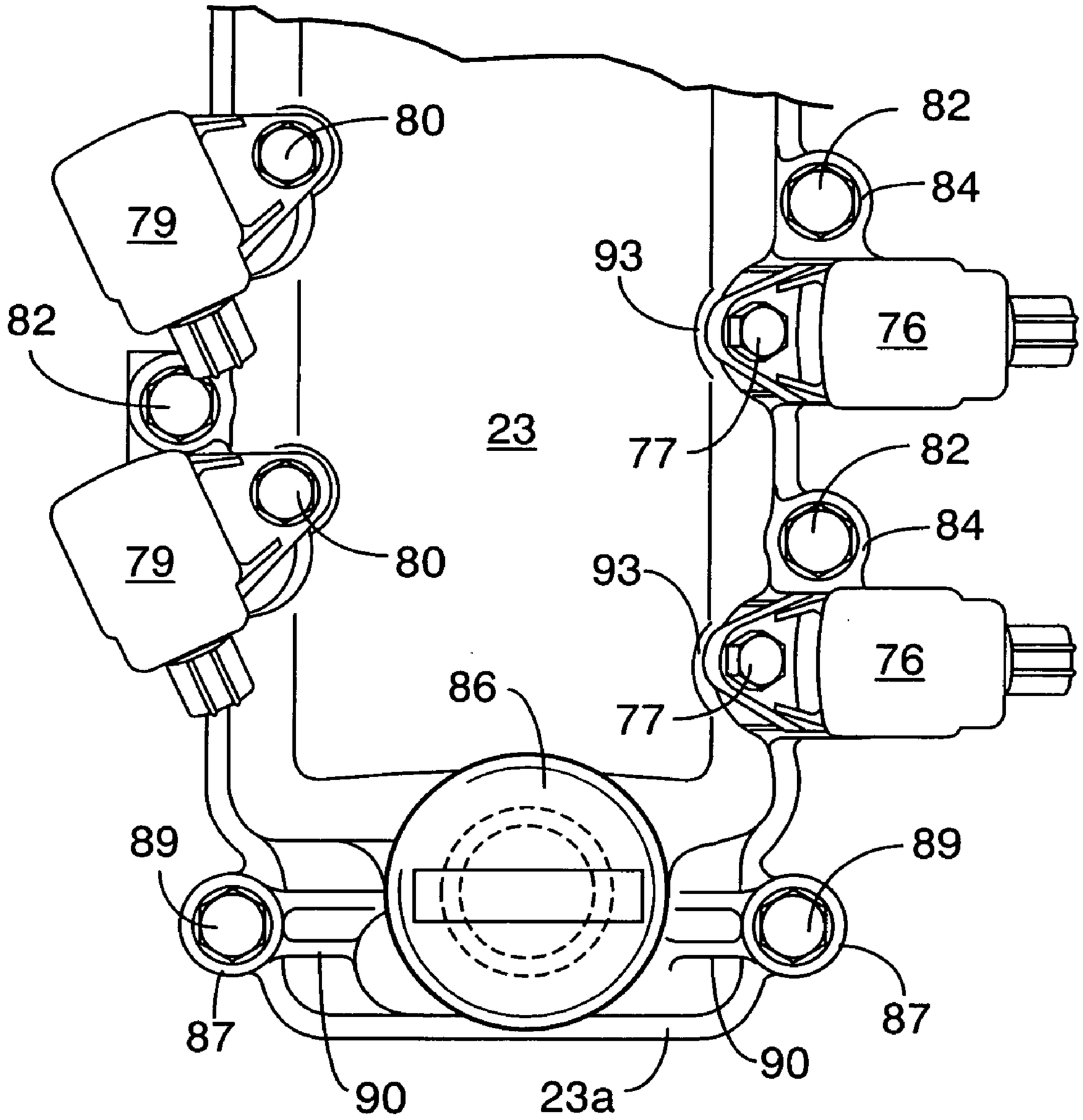

FIG.9

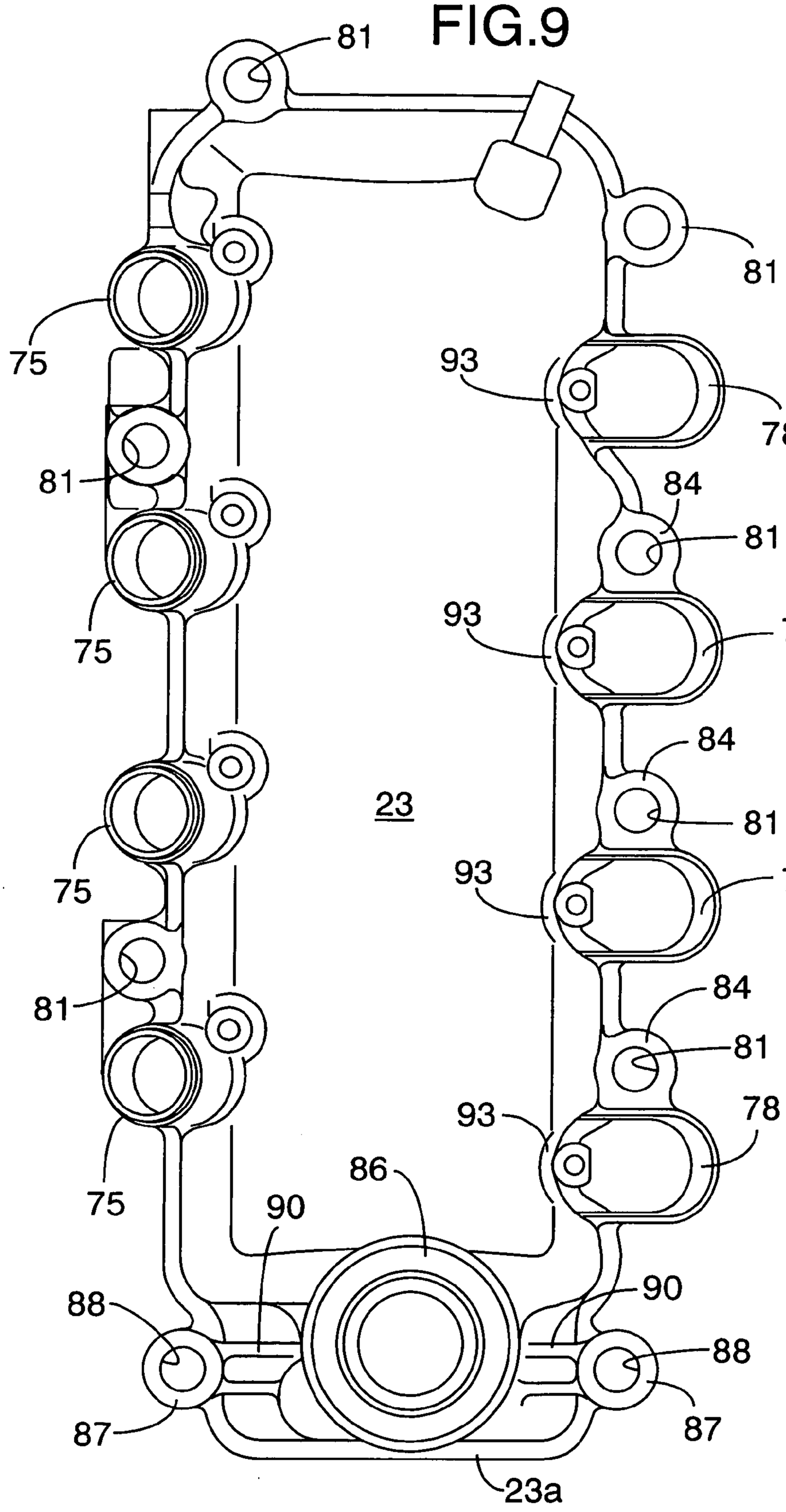
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FIG.10

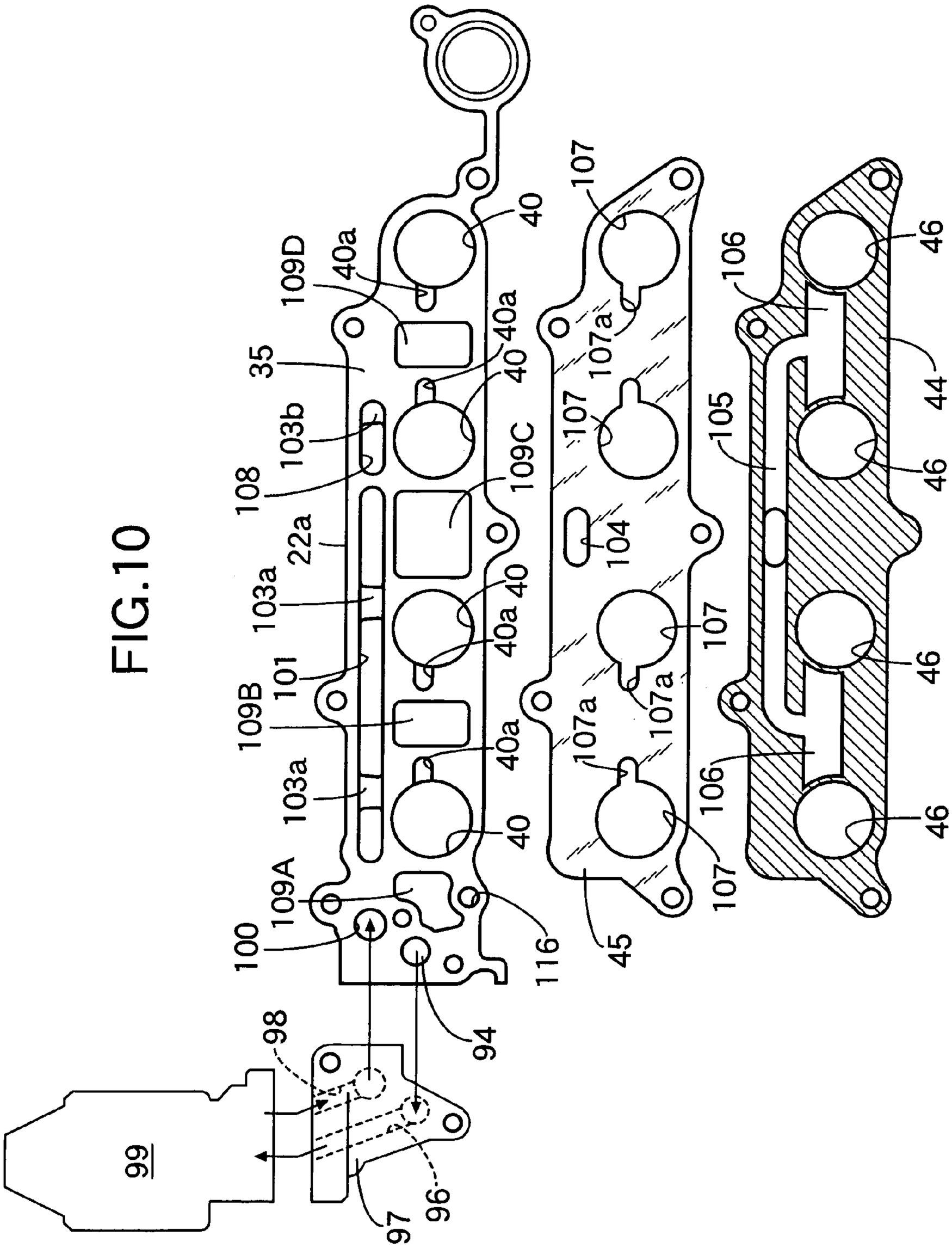
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FIG.11

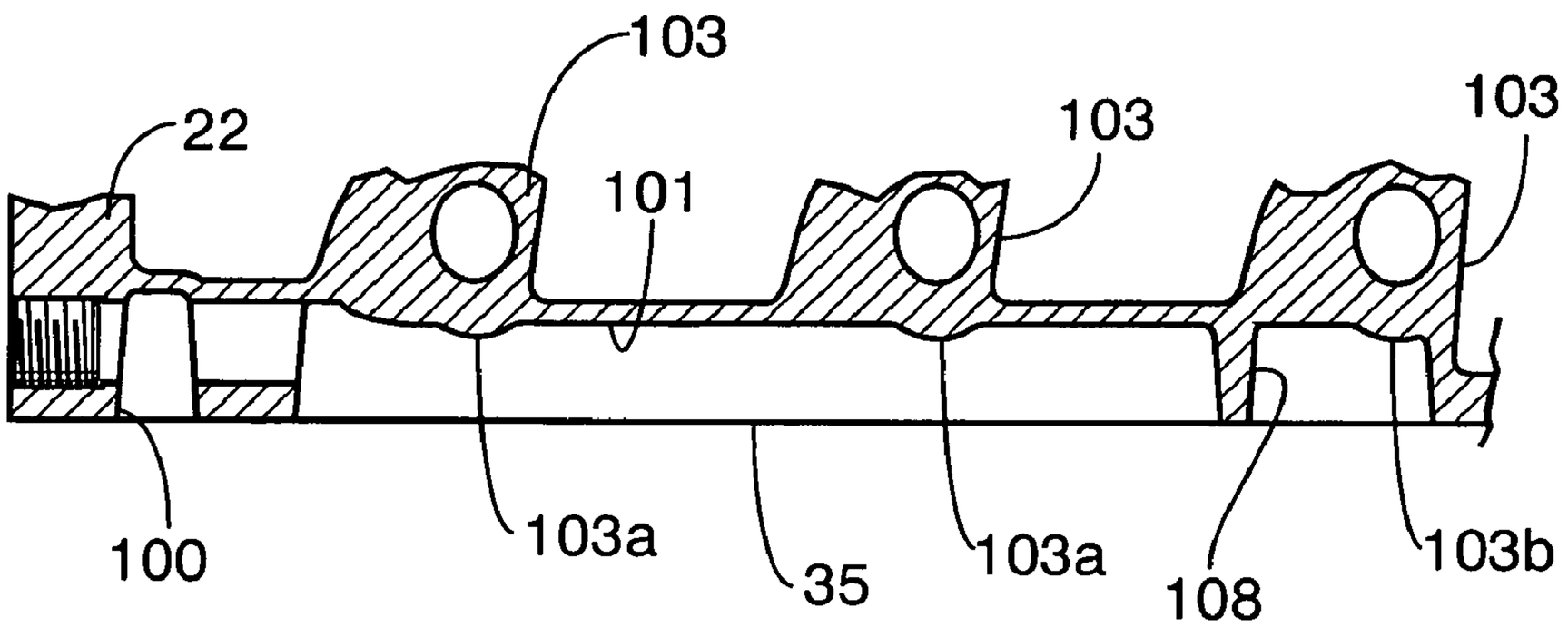

FIG.12

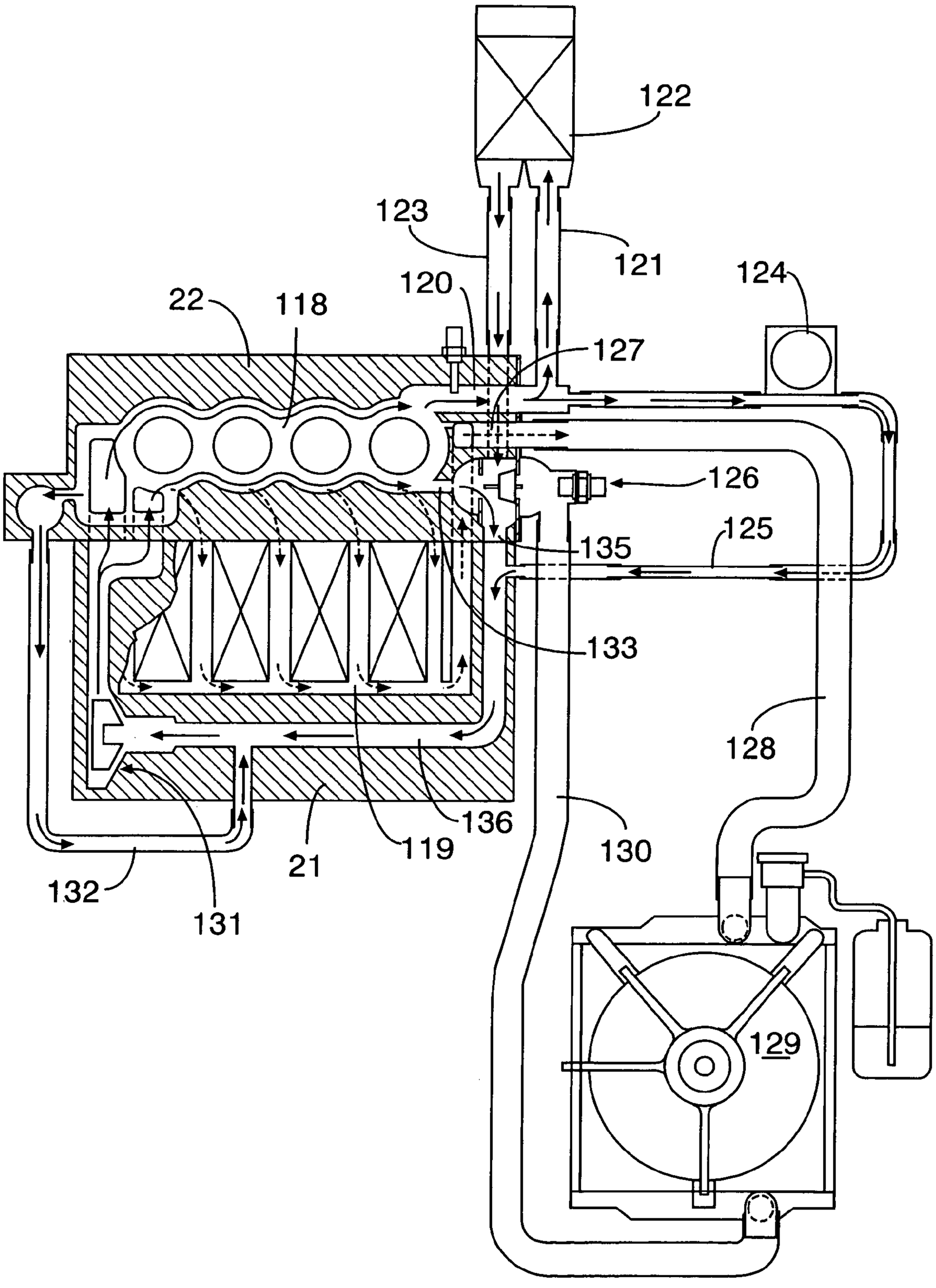
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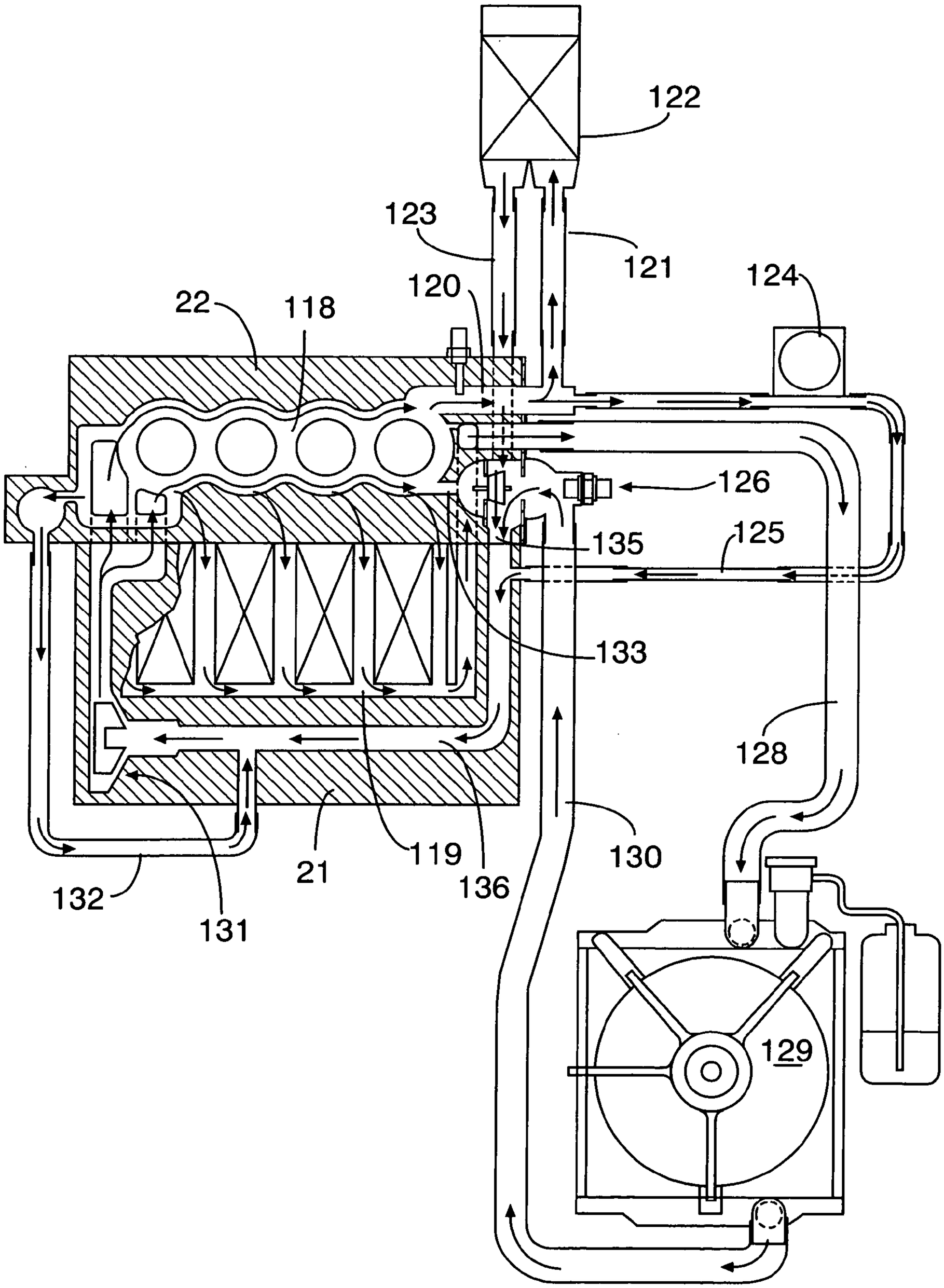
FIG.13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SOHC TYPE ENGINE

FIELD OF THE INVENTION

The present invention relates to an SOHC-type engine and particularly, to an SOHC-type engine in which first and second insertion/removal guide sections for guiding the insertion and removal of first and second spark plugs, respectively, are provided on a cylinder head including an intake valve and a first spark plug disposed therein and arranged along an axis of a camshaft, and an exhaust valve and a second spark plug disposed therein and arranged along the axis of the camshaft.

BACKGROUND ART

Conventionally, such engine is already known from Japanese Patent Publication No. 60-10165 and the like, for example.

In the conventional SOHC-type engine, a pair of rocker shafts are disposed on opposite sides of and above the camshaft, and an intake-side rocker arm moved following an intake-side cam on the camshaft to drive the intake valves is swingably carried on one of the rocker shafts, and an exhaust-side rocker arm moved following an exhaust-side cam on the camshaft to drive the exhaust valves is swingably carried on the other rocker shaft. Therefore, the width of the cylinder head in a direction perpendicular to the camshaft is obliged to become relatively large.

DISCLOSURE OF THE INVENTION

The present invention has been accomplished with such circumstances in view, and it is an object of the present invention to provide an SOHC-type engine, wherein the width of the cylinder head in the direction perpendicular to the axis of the camshaft can be set to be small.

To achieve such object, according to a first aspect and feature of the present invention, there is provided an SOHC-type engine in which first and second insertion/removal guide sections for guiding the insertion and removal of first and second spark plugs, respectively, are provided on a cylinder head including an intake valve and a first spark plug disposed therein and arranged along an axis of a camshaft, and an exhaust valve and a second spark plug disposed therein and arranged along the axis of the camshaft, wherein a single rocker shaft is disposed above the camshaft; an intake-side rocker arm moved following an intake-side cam provided on the camshaft to drive the intake valve and an exhaust-side rocker arm moved following an exhaust-side cam provided on the camshaft to drive the exhaust valve are carried commonly on the rocker shaft; the first insertion/removal guide section and the intake valve are disposed so as to be superposed one on another at least partially in a view of projection onto a plane perpendicular to the axis of the camshaft; and the second insertion/removal guide section and the exhaust valve are disposed so as to be superposed one on another at least partially in a view of projection onto the plane.

With such arrangement of the first feature, the intake valve and the first insertion/removal guide section as well as the exhaust valve and the second insertion/removal guide section can be disposed at locations closer to the camshaft and hence, the width of the cylinder head in the direction perpendicular to the axis of the camshaft can be set to be small, as compared with the conventional SOHC-type engine including the pair of rocker shafts.

According to a second aspect and feature of the present invention, in addition to the arrangement of the first feature, the shortest distance in the projection view between at least one of the first and second insertion/removal guide sections and the camshaft is set smaller than the shortest distance in the projection view between at least one of valve stems of the intake and exhaust valves and the camshaft. With such arrangement, at least one of the first and second insertion/removal guide sections can be disposed in more proximity to the camshaft, whereby the width of the cylinder head in the direction perpendicular to the axis of the camshaft can be set to be smaller.

According to a third aspect and feature of the present invention, in addition to the arrangement of the first feature, the shortest distance in the projection view between the first insertion/removal guide section and the camshaft is set smaller than the shortest distance in the projection view between the valve stem of the intake valve and the camshaft, and the shortest distance in the projection view between the second insertion/removal guide section and the camshaft is set smaller than the shortest distance in the projection view between the valve stem of the exhaust valve and the camshaft. With such arrangement, both of the first and second insertion/removal guide sections can be disposed in more proximity to the camshaft, whereby the width of the cylinder head in the direction perpendicular to the axis of the camshaft can be set to be further small.

According to a fourth aspect and feature of the present invention, in addition to any of the first to third features, at least one of upper ends of the first and second insertion/removal guide sections is formed, curved to protrude into a valve-operating chamber defined between the cylinder head and a head cover coupled to the cylinder head. With such arrangement, the amount of projection of the upper end of at least one of the first and second insertion/removal guide sections from the side of the cylinder head can be suppressed to a small value, thereby contributing to setting at the small value the width of the cylinder head in the direction perpendicular to the axis of the camshaft, and enhancing the rigidity of a sidewall of the cylinder head. Moreover, the inclination of at least one of the first and second spark plug can be suppressed to a small value to enhance the ignitability.

According to a fifth aspect and feature of the present invention, in addition to the arrangement of any of the first to fourth features, at least an upper portion of the first insertion/removal guide section is formed to have an arcuate cross-sectional shape opened in a direction opposite from the camshaft. With such arrangement, it is easy to form the cylinder head by casting.

According to a sixth aspect and feature of the present invention, in addition to the arrangement of any of the first to fifth features, at least one of the first and second insertion/removal guide sections is disposed at least partially between each of head bolts for fastening the cylinder head to a cylinder block at locations spaced apart from one another along the axis of the camshaft and at least one of the intake and exhaust valves. With such arrangement, at least one of the first and second insertion/removal guide sections can be disposed at least partially and effectively in a space between at least one of the intake and exhaust valves and the head bolt disposed sideways thereof, thereby providing the further compactness of the cylinder head.

According to a seventh aspect and feature of the present invention, in addition to the arrangement of any of the first to sixth features, at least one of the first and second insertion/removal guide sections is disposed at least partially between

a shaft bearing portion provided on the cylinder head to carry the camshaft thereon for rotation and at least one of the intake and exhaust valves. With such arrangement, at least one of the first and second insertion/removal guide sections can be disposed at least partially and effectively in a space between at least one of the intake and exhaust valves and the shaft bearing portion disposed sideways thereof, thereby providing the further compactness of the cylinder head.

According to an eighth aspect and feature of the present invention, in addition to the arrangement of any of the first to seventh features, the first and second insertion/removal guide sections are formed to protrude toward the valve-operating chamber at locations corresponding to contact potions of the intake-side and exhaust-side cams immersed partially in an oil bath defined on the cylinder head and the intake-side and exhaust-side rocker arms. With such arrangement, one of the intake-side and exhaust-side cams causes an oil in the oil bath to be scattered by the rotation thereof to collide against a portion of one of the first and second insertion/removal guide sections, which protrudes toward the valve-operating chamber, whereby the oil can be scattered into the valve-operating chamber. Moreover, the oil colliding against the portions of the first and second insertion/removal guide sections protruding toward the valve-operating chamber can be further scattered toward the intake-side cam and the exhaust-side cam, whereby the oil can be supplied efficiently to the contact portions of the intake-side and exhaust-side cams and the intake-side and exhaust-side rocker arms to enable the effective lubrication.

According to a ninth aspect and feature of the present invention, in addition to the arrangement of the first feature, at least an upper end of the second insertion/removal guide section is formed into a cylindrical shape, and bolts for fastening a head cover to the cylinder head are disposed between the second insertion/removal guide sections individually corresponding to a plurality of combustion chambers. With such arrangement, a portion provided on the cylinder head in order to fasten the head cover of the multi-cylinder engine to the cylinder head can be disposed so as not to protrude sideways from the side of the cylinder head to the utmost, thereby further contributing to the compactness of the cylinder head.

According to a tenth aspect and feature of the present invention, in addition to the arrangement of the first feature, a first plug holder connected to the first spark plug inserted into the first insertion/removal guide section protrudes from the cylinder head; an ignition coil connected to an upper end of the first spark plug holder are fastened to a head cover coupled to the cylinder head by a single coil bolt; and a detent portion is integrally provided on the head cover to come into contact with the upper end of the first plug holder in order to receive a load around the axis of the coil bolt acting on a protrusion of the first plug holder from the cylinder head during tightening of the coil bolt. With such arrangement, the ignition coil can be mounted to the head cover by a very simple mounting operation and moreover, a forcible load can be prevented from acting on the ignition plug, while avoiding an increase in number of parts. In addition, the rigidity of the head cover can be enhanced by the detent portion.

According to an eleventh aspect and feature of the present invention, in addition to the arrangement of the tenth feature, bolts for fastening the head cover to the cylinder head are disposed between the detent portions individually corresponding to a plurality of combustion chambers. With such arrangement, a portion provided on the cylinder head to fasten the head cover to the cylinder head can be disposed so as not to protrude sideways from the side of the cylinder head to the utmost, thereby further contributing to the compactness of the cylinder head and providing a reduction in weight of the cylinder head.

According to a twelfth aspect and feature of the present invention, in addition to the arrangement of the tenth or eleventh feature, each of the detent portions is formed into a ring shape. With such arrangement, the rigidity of the head cover can be further enhanced.

According to a thirteenth aspect and feature of the present invention, in addition to the arrangement of any of the tenth to twelfth features, a fastening boss for fastening the ignition coil is provided on the head cover inside the detent portion. With such arrangement, it is possible to avoid an increase in size of the head cover due to the fastening of the ignition coil.

According to a fourteenth aspect and feature of the present invention, in addition to the arrangement of any of the tenth to thirteenth features, a resilient member is mounted between the detent portion and the first plug holder. With such arrangement, the transmission of the vibration of the engine to the ignition coil can be moderated and hence, the durability of the ignition coil can be maintained at a high level.

According to a fifteenth aspect and feature of the present invention, in addition to the arrangement of the first feature, upper end faces of the first and second insertion/removal guide sections are formed in the same plane, and a head cover is coupled to the upper end faces of the first and second insertion/removal guide sections. With such arrangement, the upper end faces of the first and second insertion/removal guide sections can be worked simultaneously, leading to a good workability.

According to a sixteenth aspect and feature of the present invention, in addition to the arrangement of the first feature, an upper portion of the first insertion/removal guide section, into which the first plug holder connected to the first spark plug is inserted, is formed to have an arcuate cross-sectional shape opened forwards in a direction of forward movement of the vehicle. With such arrangement, travel wind generated with the forward movement of the vehicle strikes directly against the first plug holder to effectively cool the first plug holder.

According to a seventeenth aspect and feature of the present invention, in addition to the arrangement of the first feature, an upper portion of the first insertion/removal guide section is formed to have an arcuate cross-sectional shape opened in a direction opposite from the camshaft, and a boss for mounting a fuel injection valve is provided on the cylinder head at a location adjoining a lower portion of the first insertion/removal guide section in a direction along the axis of the camshaft. With such arrangement, it is easy to form the cylinder head by casting, and moreover, the fuel injection valve can be disposed in more proximity to the first spark plug, while avoiding the interference with the first insertion/removal guide section, thereby contributing to the compactness of the engine.

According to an eighteenth aspect and feature of the present invention, in addition to the arrangement of the first feature, a boss for mounting a fuel injection valve is provided on the cylinder head so as to be integrally connected at no distance to the first insertion/removal guide section. With such arrangement, the rigidity of the boss can be enhanced.

According to a nineteenth aspect and feature of the present invention, in addition to the arrangement of the first feature, the second insertion/removal guide section, the

intake-side rocker arm, the intake valve and a boss provided on the cylinder head in order to mount the fuel injection valve are disposed substantially side by side on the same plane perpendicular to the axis of the camshaft. With such arrangement, the cylinder head can be formed further compactly.

According to a twentieth aspect and feature of the present invention, in addition to the arrangement of the first feature, a protrusion is integrally provided on the cylinder head to project outwards and sideways from the cylinder block; a spark plug chamber faced by a portion of the first spark plug is defined in the cylinder head in such a manner that a portion of the spark plug chamber is disposed on the protrusion; and a drainage bore is provided in the protrusion, so that one end thereof opens into a lower portion of the spark plug chamber and the other end thereof opens into an outer surface of a lower portion of the protrusion. With such arrangement, the volume of the spark plug chamber can be set at a relatively large value to provide a reduction in weight of the cylinder head, and water entering into the spark plug chamber can be discharged reliably by the drainage bores shortened in length and simplified.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. **1** to **13** show an embodiment of the present invention.

FIG. **1** is a vertical sectional view of an upper portion of an engine, taken along a line **1**—**1** in FIG. **3**;

FIG. **2** is a vertical sectional view of the upper portion of the engine, taken along a line **2**—**2** in FIG. **3**;

FIG. **3** is across-sectional view of a cylinder head, taken along a line **3**—**3** in FIG. **2**;

FIG. **4** is a plan view taken along a line **4**—**4** in FIG. **1** for showing the arrangement in a valve-operating chamber;

FIG. **5** is a side view of the cylinder head, taken in the direction of an arrow **5** in FIG. **4**;

FIG. **6** is a bottom view of the cylinder head, taken in the direction of an arrow **6** in FIG. **5**;

FIG. **7** is a sectional view of the cylinder head, taken along a line **7**—**7** in FIG. **3**;

FIG. **8** is a plan view taken in the direction of an arrow **8** in FIG. **1**;

FIG. **9** is a plan view of the entire arrangement of a head cover;

FIG. **10** is a view for explaining the flowing of an EGR gas among an intake-side fastening face of the cylinder head, a gasket and a plate;

FIG. **11** is a sectional view taken along a line **11**—**11** in FIG. **5**;

FIG. **12** is a view of a cooling water system showing the flowing of cooling water when the engine is cold; and

FIG. **13** is a view of the cooling water system showing the flowing of cooling water when the engine is hot.

BEST MODE FOR CARRYING OUT THE INVENTION

Referring first to FIGS. **1** to **6**, an engine is a multi-cylinder, e.g., 4-cylinder SOHC-type engine. The engine is mounted in a vehicle and includes a cylinder block **21**, a cylinder head **22** fastened to an upper surface of the cylinder block **21** through a gasket **24**, and a head cover **23** fastened to an upper surface of the cylinder head **22** through a gasket **25** and defining a valve-operating chamber **26** between the head cover **23** and the cylinder head **22**.

Four cylinder bores **27** are provided in the cylinder block **21** and arrange in line in a lateral direction perpendicular to a direction **31** of forward movement of the vehicle, and recesses **30** are provided in a lower surface of the cylinder head **22** and arranged in line to define first, second, third and fourth combustion chambers **29**A, **29**B, **29**C and **29**D between the recesses **30** and the cylinder block **21**, respectively, so that tops of pistons **28** slidably received in the cylinder bores **27** face the combustion chambers **29**A, **29**B, **29**C and **29**D, respectively.

Referring also to FIG. **7**, five shaft bearing portions **32** are integrally provided at an upper portion of the cylinder head **22** at a substantially central location in a direction perpendicular to a direction of arrangement of the first to fourth combustion chambers **29**A to **29**D in such a manner that the first to fourth combustion chambers **29**A to **29**D are interposed therebetween, and circular bearing bores **33** are provided coaxially in the shaft bearing portions **32**. On the other hand, A camshaft **34** having an axis extending in parallel to the direction of arrangement of the first to fourth combustion chambers **29**A to **29**D is disposed in the valve-operating chamber **26** above the combustion chambers **29**A to **29**D and rotatably carried on the shaft bearing portions **32**. Specifically, five circular support portions **34***a* are integrally provided on the camshaft **34** at locations axially spaced apart from one another and in correspondence to the shaft bearing portions **32** to protrude radially outwards, and are inserted through and supported in the bearing bores **33**, whereby the camshaft **34** is rotatably carried on the cylinder head **22**.

Protrusions **22***a* and **22***b* are integrally provided on opposite sides of the cylinder head **22** commonly to the combustion chambers **29**A to **29**D to project outwards from the cylinder block **21**. One **22***a* of the protrusions **22***a* and **22***b*, which faces forwards in the direction **31** of forward movement of the vehicle, is formed at its outer end with an intake-side fastening face **35** which is a flat face parallel to the camshaft **34**, and the other protrusion **22***b* facing backwards in the direction **31** of forward movement of the vehicle is formed at its outer end with an exhaust-side fastening face **36** as a flat face parallel to the camshaft **34**.

Intake ports **40** and exhaust ports **41** are provided in the cylinder head **22** one by one for each of combustion chambers **29**A to **29**D. Outer ends of the intake ports **40** open into the intake-side fastening face **35**, and outer ends of the exhaust ports **41** open into the exhaust-side fastening face **36**.

An intake device **42** is fastened to the intake-side fastening face **35** and includes an intake manifold **43** having a flange **43***a* common to the intake ports **40**, and a plate **44** put into abutment against the flange **43***a* and having passages **46** individually corresponding to the intake ports **40**. The intake device **42** is fastened to the intake-side fastening face **35** in such a manner that a gasket **45** is interposed between the plate **44** and the intake-side fastening face **35**. In addition, an exhaust device (not shown) is fastened to the exhaust-side fastening face **36**.

Intake valves **47** are openably and closably disposed in the cylinder head **22** and interposed between inner ends of the intake ports **40** and the combustion chambers **29**A to **29**D, and exhaust valves **48** are also openably and closably disposed in the cylinder head **22** and interposed between inner ends of the exhaust ports **41** and the combustion chambers **29**A to **29**D.

Each of the intake valves **47** has a valve stem **47***a*, which is slidably received in a guide tube **49** provided in the cylinder head **22** to protrude into the valve-operating chamber **26**, and the intake valve **47** is biased into a closing

direction by a valve spring **51** mounted under compression between a retainer **50** mounted at an upper end of the valve stem **47***a* and the cylinder head **22**. Each of the exhaust valves **48** has a valve stem **48***a*, which is slidably received in a guide tube **52** provided in the cylinder head **22** to protrude into the valve-operating chamber **26**, and the exhaust valve **48** is biased into a closing direction by a valve spring **54** mounted under compression between a retainer **53** mounted at an upper end of the valve stem **48***a* and the cylinder head **22**.

A single rocker shaft **55** having an axis parallel to the camshaft **34** is disposed in the valve-operating chamber **26** and fixed to the cylinder head **22** above the camshaft **34**. Specifically, the rocker shaft **55** is fastened by bolts **56** to upper surfaces of the shaft bearing portions **32** provided on the cylinder head **22** to carry the camshaft **34** for rotation.

The intake valves **47** and the exhaust valves **48** for every combustion chamber **29**A to **29**D are disposed at locations displaced from one another along the axes of the camshaft **34** and the rocker shaft **55**. Intake-side cams **57** corresponding to the intake valves **47** and exhaust-side cams **58** corresponding to the exhaust valves **48** are integrally provided on the camshaft **34** for every combustion chamber **29**A to **29**D. A radius of a circular locus described by each of tops of the intake-side cams **57** and the exhaust-side cams **58** is set smaller than a radius of the support portion **34***a* included in the camshaft **34**, whereby the camshaft **34** can be inserted through and supported in the shaft-bearing portions **32** of the cylinder head **22**.

Swingably carried on the rocker shaft **55** are intake-side rocker arms **59** moved following the intake-side cams **57** on the camshaft **34** to drive the intake valves **47**, and exhaust-side rocker arms **60** moved following the exhaust-side cams **58** on the camshaft **34** to drive the exhaust valves **48**.

Each of the intake-side rocker arms **59** includes a cylindrical boss portion **59***a* swingably carried on the rocker shaft **55**, and an arm portion **59***b* extending in a direction perpendicular to the axis of the rocker shaft **55** and integrally connected to the boss portion. A roller **61** pivotally supported at one end of the arm portion **59***b* is in rolling contact with the intake-side cam **57**, and a tappet screw **62**, which is threadedly engaged with the other end of the arm portion **59***b* so that its advanced/retracted position can be adjusted, is in abutment against an upper end of the valve stem **47***a* of the intake valve **47**.

The exhaust-side rocker arm **60** includes a cylindrical boss portion **60***a* swingably carried on the rocker shaft **55**, and an arm portion **60***b* extending in a direction perpendicular to the axis of the rocker shaft **55** and integrally connected to the boss portion **60***a*. A roller **63** pivotally supported at one end of the arm portion **60***b* is in rolling contact with the exhaust-side cam **58**, and a tappet screw **64**, which is threadedly engaged with the other end of the arm portion **60***b* so that its advanced/retracted position can be adjusted, is in abutment against an upper end of the valve stem **48***a* of the exhaust valve **48**.

The intake-side rocker arm **59** and the exhaust-side rocker arm **60** are swingably mounted on the rocker shaft **55** in such a manner that a spring **65** surrounding the rocker shaft **55** is interposed between the boss portions **59***a* and **60***a* of the rocker arms **59** and **60**, and the axial movement of the boss portions **59***a* and **60***a* are restricted by the shaft bearing portions **32** of the cylinder head **22**, and the positioning of the intake-side rocker arm **59** and the exhaust-side rocker arm **60** in a direction along the axis of the rocker shaft **55** can be performed by the single spring **65**, leading to a reduction in number of parts, as compared with a case where springs are interposed between the rocker shaft **55** and the shaft bearing portions **32**.

The boss portions **59***a* and **60***a* are formed to extend from the arm portions **59***b* and **60***b* toward the shaft bearing portions **32** to come into sliding direct contact with the shaft bearing portions **32**. By utilizing such structure, the number of parts can be reduced, as compared with a structure in which collars are interposed between the boss portions **59***a* and **60***a* and the shaft bearing portions **32**.

The arm portions **59***b* and **60***b* interposed between the intake-side cam **57** as well as the exhaust-side cam **58** and the intake valve **47** as well as the exhaust valve **48** are formed to extend in the direction perpendicular to the axis of the rocker shaft **55**. Therefore, as compared with a case where arm portions are curved, the rigidity of the arm portions **59***b* and **60***b* on which a valve-operating load is applied can be enhanced, and the size of a space required for placement of the intake-side rocker arm **59** and the exhaust-side rocker arm **60** in the direction along the axis of the camshaft **34** can be suppressed to a small value, which can contribute to a reduction in size of the cylinder head **22** in the direction along the axis of the camshaft **34**.

First and second spark plugs **66** and **67** with their axes disposed in a plane perpendicular to the axis of the camshaft **34** are disposed in the cylinder head **22** in correspondence to the first to fourth combustion chambers **29**A to **29**D in such a manner that they are threadedly fitted into threaded bores **66***a* and **67***a* provided in the cylinder head **22**. The first spark plugs **66** arranged side by side with the exhaust valves **48** in the direction perpendicular to the axis of the camshaft **34** are disposed so as to be arranged side by side with the intake valves **47** along the axis of the camshaft **34**, and the second spark plugs **67** arranged side by side with the intake valves **47** in the direction perpendicular to the axis of the camshaft **34** are disposed so as to be arranged side by side with the exhaust valves **48** along the axis of the camshaft **34**.

In other words, the first spark plugs **66** arranged side by side with upstream ends of the exhaust ports **41** in the direction perpendicular to the axis of the camshaft **34** are disposed so as to be arranged side by side with the intake valves **47** along the axis of the camshaft **34**, and the second spark plugs **67** arranged side by side with downstream ends of the intake ports **40** in the direction perpendicular to the axis of the camshaft **34** are disposed so as to be arranged side by side with the exhaust valves **48** along the axis of the camshaft **34**. The upstream end of each of the intake ports **40** is disposed offset to one side from a downstream end of the intake port **40** in the direction along the axis of the camshaft **34**, and a downstream end of each of the exhaust ports **41** is disposed offset to the other side from the upstream end of the exhaust port **41** in the direction along the axis of the camshaft **34**.

By determining the disposition of the intake and exhaust ports **40** and **41** and the first and second spark plugs **66** and **67**, as described above, a flow of intake air from each of the intake ports **40** produces a swirl flow in each of the combustion chambers **29**A to **29**D to enhance the combustion efficiency, while ensuring areas of the downstream ends of the intake ports **40** opening into the combustion chambers **29**A to **29**D and areas of the upstream ends of the exhaust ports **41** opening into the combustion chambers **29**A to **29**D at large values to the utmost.

Moreover, the intake ports **40** and the exhaust ports **41** are provided in a curved fashion in the cylinder head **22**, so that a position PI of a central portion of the upstream end, i.e., a central portion of the outer end of each of the intake ports **40**

and a position PO of a central portion of the downstream end, i.e., a central portion of the outer end of each of the exhaust ports **41** coincide with each other in the direction along the axis of the camshaft **34**.

First insertion and removal guide portions **68** for guiding the insertion and removal of the first spark plugs **66** are integrally provided on the cylinder head **22** for every combustion chamber **29**A to **29**D, and second insertion and removal guide portions **69** for guiding the insertion and removal of the second spark plugs **67** are integrally provided on the cylinder head **22** for every combustion chamber **29**A to **29**D.

Each of the first insertion/removal guide sections **68** is formed so as to have an arcuate cross-sectional shape opened in a direction opposite from the camshaft **34** (forwards in the direction **31** of forward movement of the vehicle) at least at its upper portion, e.g., at its upper and lower portions excluding its vertically intermediate portion in the present embodiment. Therefore, the formation of the cylinder head **22** by casting is facilitated by defining the shape of the first insertion/removal guide section **68** in the above manner. Each of the second insertion/removal guide sections **69** is integrally provided on the cylinder head **22** with at least its upper end, e.g., the entire region in the present embodiment being formed cylindrically.

Upper end faces of the first and second insertion/removal guide sections **68** and **69** are formed in the same plane, and the head cover **23** is fastened to the upper end faces of the first and second insertion/removal guide sections **68** and **69** with the gasket **25** interposed therebetween. With such a construction, the upper end faces of the first and second insertion/removal guide sections **68** and **69** can be worked simultaneously, leading to an improved workability.

Referring particularly carefully to FIG. **1**, the first insertion/removal guide section **68** and the intake valve **47** are disposed so as to be superposed one on another at least partially in a view of projection onto a plane perpendicular to the axis of the camshaft **34**, and the second insertion/removal guide section **69** and the exhaust valve **48** are disposed so as to be superposed one on another at least partially in a view of projection onto such plane. Moreover, the shortest distance in the projection view between at least one (both in the present embodiment) of the first and second insertion/removal guide sections **68** and **69** and the camshaft **34** is set smaller than the shortest distance in the projection view between at least one (both in the present embodiment) of the valve stems **47***a* and **48***a* of the intake valve **47** and the exhaust valve **48** and the camshaft **34**. More specifically, in the present embodiment, if the shortest distance in the projection view between the valve stem **47***a* of the intake valve **47** and the camshaft **34** is represented by L**1**, and the shortest distance in the projection view between the first insertion/removal guide section **68** and the camshaft **34** is represented by L**2**, the shortest distances L**1** and L**2** are determined so that a relation, L**2**<L**1** is established, and the relative positional relationship between the valve stem **48***a* of the exhaust valve **48** as well as the second insertion/removal guide section **69** and the camshaft **34** is determined in a similar manner.

At least one, e.g., both, in the present embodiment, of the upper ends of the first second insertion/removal guide sections **68** and **69** is formed in a curved configuration to protrude into the valve-operating chamber **26** between the cylinder head **22** and the head cover **23**.

Referring particularly carefully to FIG. **4**, the cylinder head **22** is fastened to the cylinder block **21** by head bolts **70** disposed plurality by plurality, e.g., five by five on opposite sides at distances in the axial direction of the camshaft **34**. The first and second insertion/removal guide sections **68** and **69** are disposed at least in part between the head bolts **70** and at least one (both in the present embodiment) of the intake valves **47** and the exhaust valves **48** and are disposed effectively by curving at least in part in spaces between the intake and exhaust valves **47** and **48** and the head bolts **70** disposed sideways of the valves **47** and **48**. This can contribute to the compactness of the cylinder head **22** in a widthwise direction perpendicular to the axis of the camshaft **34**.

At least one of the first and second insertion/removal guide sections **68** and **69** is disposed at least in part between at least one of the intake valves **47** and the exhaust valves **48** and the head bolts **70** adjoining at least one of the intake valves **47** and the exhaust valves **48**. In the present embodiment, a portion of the first insertion/removal guide section **68** is disposed between the intake valve **47** and the head bolt **70** adjoining the intake valve **47**, and a portion of the second insertion/removal guide section **69** is disposed between the exhaust valve **48** and the head bolt **70** adjoining the exhaust valve **48**. Thus, portions of the first and second insertion/removal guide sections **68** and **69** are disposed effectively in the spaces between the intake valves **47** as well as the exhaust valves **48** and the head bolts **70** disposed sideways of the valves **47** and **48**. This can contribute to the compactness of the cylinder head **22** in the axial direction of the camshaft **34**.

At least one of the first and second insertion/removal guide sections **68** and **69** are disposed at least in part between the shaft bearing portions **32** of the cylinder head **22** and at least one of the intake valves **47** and the exhaust valves **48**. In the present embodiment, portions of the first insertion/removal guide sections **68** are disposed between the shaft bearing portions **32** and the intake valves **47**, and portions of the second insertion/removal guide sections **69** are disposed between the shaft bearing portions **32** and the exhaust valves **48**. With such dispositions, portions of the first insertion/removal guide sections **68** are disposed effectively in the spaces between the intake valves **47** and the shaft bearing portions **32** disposed sideways of the intake valves **47**, and portions of the second insertion/removal guide sections **69** are disposed effectively in the spaces between the exhaust valves **48** and the shaft bearing portions **32** disposed sideways of the exhaust valves **48**. This can contribute to the further compactness of the cylinder head **22** in the axial direction of the camshaft **34**.

Further, upper portions of the first and second insertion/removal guide sections **68** and **69** are formed in a curved manner to protrude toward the valve-operating chamber **26**, and such protrusions are disposed at locations corresponding to contact portions of the intake-side cams **57** and the exhaust cams **58** partially immersed in an oil bath **71** (see FIGS. **1** and **2**) defined on the cylinder head **22** with the rollers **61** and **63** provided on the intake-side rocker arms **59** and the exhaust-side rocker arms **60**.

Therefore, the oil in the oil bath **71** is allowed by the exhaust-side cams **58** to collide against the protruding portions of the second insertion/removal guide sections **69** toward the valve-operating chamber **26** in response to the rotation of the camshaft **34** in a rotational direction **72** shown by an arrow in FIGS. **1** and **2**, whereby the oil is scattered effectively into the valve-operating chamber **26**. Moreover, the protrusions of the first and second insertion/removal guide sections **68** and **69** toward the valve-operating chamber **26** are disposed at locations corresponding to contact portions of the intake-side cams **57** as well as the exhaust-

side cams **58** with the rollers **61** of the intake-side rocker arms **59** as well as the rollers **63** of the exhaust-side rocker arms **60** and hence, the oil scattered into the valve-operating chamber **26** is allowed to collide against the protrusions, whereby the oil is supplied efficiently to the contact portions to enable the effective lubrication of the contact portions.

The first and second spark plugs **66** and **67** is mounted at lower ends of first and second bar-shaped plug holders **73** and **74** removably inserted into the first and second insertion/removal guide sections **68** and **69**, respectively.

The first insertion/removal guide section **68** has a cylindrical portion **68***a* at its vertically intermediate portion, and the first plug holder **73** is inserted into the first insertion/removal guide section **68** and has, at its intermediate portion, a sealing portion **73***a* which is resiliently brought into contact with the entire inner periphery of the cylindrical portion **68***a*. An upper portion of the first plug holder **73** protrudes from the cylinder head **22**. The second plug holder **74** is inserted into the second insertion/removal guide section **69** which is cylindrical. On the other hand, the head cover **23** is provided with cylindrical portions **75** coaxially connected at their lower ends to upper ends of the second insertion/removal guide sections **69** provided in the cylindrical shape on the cylinder head **22**, and the second plug holders **74** are inserted into the cylindrical portions **75** above the second insertion/removal guide sections **69**. Ring-shaped resilient members **91** for moderating the transmission of the vibration of the engine to the second plug holders **74** are mounted between the second plug holders **74** and the cylindrical portions **75**.

Referring also to FIGS. **8** and **9**, ignition coils **76** are connected individually to upper ends of the first plug holders **73** inserted into the first insertion/removal guide sections **68** and protruding upwards from the cylinder head **22**, and are fastened to the head cover **23** by coil bolts **77** each provided in correspondence to each of the combustion chambers **29**A to **29**D.

Upper portions of the first plug holders **73** protrude upwards from the cylinder head **22**. In order to inhibit a turning force in a tightening direction of the coil bolts **77** from acting on portions of the first plug holders **73** protruding upwards from the cylinder head **22** to cause a forcible load to be applied to such protrusions, when the ignition coils **76** are fastened to the head cover **23** by the coil bolts **77**, detent portions **78** contacting with outer peripheries of the upper ends of the first plug holders **73** are integrally provided on the head cover **23**, for example, in a ring shape through which the upper ends of the first plug holders **73** are inserted. Therefore, the ignition coils **76** can be mounted to the head cover **23** by a very simple mounting operation, and it is possible to prevent a forcible load from being applied to the first spark plugs **66**, while avoiding an increase in number of parts. In addition, the rigidity of the head cover **23** can be enhanced by the detent portions **78**.

Moreover, the coil bolts **77** are threadedly engaged with fastening bosses **93** provided on the head cover **23** inside the detent portions **78** in order to avoid that the size of the head cover **23** is increased for the fastening of the ignition coils **76**.

Ring-shaped resilient members **92** are mounted between the upper ends of the first plug holders **73** and the detent portions **78** and hence, the transmission of the vibration of the engine to the ignition coils **76** and **79** can be moderated by the resilient members **91** and **92**, and the durability of the ignition coils **76** and **79** can be maintained at a high level.

Further, each of the upper portions of the first insertion/removal guide sections **68** inserted into the first plug holders **73** has an arcuate cross-sectional shape opened forwards in the direction **31** of forward movement of the vehicle in such a manner that the upper portions of the first plug holders **73** are exposed to the outside. Thus, travel wind produced with the forward movement of the vehicle strikes directly against the upper portions of the first plug holders **73**, thereby effectively cooling the first plug holders **73**.

On the other hand, the ignition coils **79** connected individually to the upper ends of the second plug holders **74** are fastened to the head cover **23** by the coil bolts **80** each provided in correspondence to each of the combustion chambers **29**A to **29**D. In addition, the upper portions of the second plug holders **74** are inserted into the cylindrical portions **75** of the head cover **23** and hence, a force applied to the upper portions of the second plug holders **74** upon tightening of the coil bolts **80** is received by the cylindrical portions **75**. In addition, the second plug holders **74** are covered from the outside with the second insertion/removal guide sections **69** and the cylindrical portions **75** connected to each other in a cylindrical shape, and the cylindrical portions **75** are interposed between an exhaust device (not shown) and the ignition coils **79**. Therefore, an adverse affection due to a dissipation of heat from the exhaust device is inhibited as much as possible from being exerted to the second plug holders **74** and the ignition coils **79**.

The head cover **23** is fastened to the cylinder head **22** at a plurality of points, e.g., at seven points spaced apart from one another in a circumferential direction thereof, and the bolts **82** inserted through the insertion bores **81** provided in the head cover **23** are threadedly engaged into the threaded bores **83** provided in the upper surface of the cylinder head **22**.

Among the insertion bores **81**, the bolts **82** and the threaded bores **83** provided at the plurality of points, for example, the insertion bores **81**, the bolts **82** and the threaded bores **83** provided at the three points are disposed between the detent portions **78**. As a result, it can be ensured that a portion provided on the cylinder head **22** for fastening the head cover **23** to the cylinder head **22** does not protrude sideways from a side of the cylinder head **22** to the utmost. This can contribute to the compactness of the cylinder head **22** and can prevent a forcible load from acting on the second plug holders **73**, while providing a reduction in weight of the cylinder head **22**.

The three insertion bores **81** disposed between the detent portions **78** are provided in portions **84** to be fastened, which are connected directly to the three detent portions **78** and hence, the rigidities of the portions **84** to be fastened and the detent portions **78** can be increased.

Among the insertion bores **81**, the bolts **82** and the threaded bores **83**, for example, the insertion bores **81**, the bolts **82** and the threaded bores **83** provided at the two points are disposed between the second insertion/removal guide sections **69** which are cylindrical. This also ensures that the portion provided on the cylinder head **22** for fastening the head cover **23** to the cylinder head **22** does not protrude sideways from the side of the cylinder head **22** to the utmost, which can contribute further to the compactness of the cylinder head **22**.

The head cover **23** has a bulge **23***a* protruding from the cylinder head **22** at one end thereof in the axial direction of the camshaft **34**. The bulge **23***a* is fastened to a chain cover (not shown) which is a cover for covering a power-transmitting mechanism. Integrally provided on the bulge **23***a* are an oil supply tube **86** protruding upwards and detachably closed by an oil filler cap **85**, and fastening boss portions **87**, **87** disposed on opposite sides of the oil supply tube **86**, and

bolts **88**, **88** inserted respectively through the fastening boss portions **87**, **87** are threadedly engaged with the chain cover. Therefore, it is possible to enhance the operability of attaching and detaching the oil filler cap **85** and to increase the fastening rigidities of the head cover **23** and the chain cover by the oil supply tube **86** having a high rigidity.

Moreover, the bulge **23***a* has ribs **90**, **90** integrally formed on its upper surface for connecting the oil supply tube **86** and the fastening boss portions **87**, **87** to each other, and the rigidities of the oil supply tube **86** and the fastening boss portions **87**, **87** are increased by the ribs **90**, **90**. A first EGR passage **94** is provided in the cylinder head **22** at one end in the direction along the axis of the camshaft **34** to extend in the direction perpendicular to the axis of the camshaft **34**. One end of the first EGR passage **94** communicates with the exhaust port **41** in the first combustion chamber **29**A through a communication bore **95** provided in the cylinder head **22**, and the other end of the first EGR passage **94** opens into the intake-side fastening face **35**.

The first EGR passage **94** is disposed at a location where the exhaust port **41** in the first combustion chamber **29**A is interposed between the first EGR passage **94** and the second insertion/removal guide section **69** of the first combustion chamber **29**A, i.e., the second spark plug **67**, and the exhaust port **41** is permitted to communicate with the first EGR passage **94** by the communication bore **95** extending rectilinearly, whereby the structure of communication between the exhaust port **41** and the first EGR passage **94** can be simplified. In addition, the first EGR passage **94** is disposed at a location where the first insertion/removal guide section **68** of the first combustion chamber **29**A, i.e., the first spark plug **66** is interposed between the first EGR passage **94** and the intake port **40**. Thus, it is possible to inhibit the exertion of an adverse affection due to the heat from the first EGR passage **94** to the air flowing through the intake port **40**.

Referring to FIG. **10**, a passage member **97** having an inlet-side passage **96** leading to the first EGR passage **94** is fastened to the intake-side fastening face **35** at one end in the axial direction of the camshaft **34**. An EGR valve **99** is mounted to the passage member **97** for controlling the flowing of an EGR gas between the inlet-side passage **96** and an outlet-side passage **98** provided in the passage member **97**. Namely, the EGR valve **99** for controlling the flowing of the EGR gas is mounted to a sidewall of the cylinder head **22**, into which the upstream end of the intake port **40** opens, and the intake port **40** in the first combustion chamber **29**A is disposed between the first insertion/removal guide section **68** of the first combustion chamber **29**A, i.e., the first spark plug **66** and the EGR valve **99**. This also can inhibit the exertion of the adverse affection due to the heat from the EGR valve **99** to the air flowing through the intake port **40** in the first combustion chamber **29**A.

Further, referring also to FIG. **11**, the cylinder head **22** is provided, at its portion corresponding to the passage member **97**, with a communication bore **100** which opens at its outer end into the intake-side fastening face **35** to lead to the outlet-side passage **98** in the passage member **97**, and a second EGR passage **101** leading to an inner end of the communication bore **100**. The second EGR passage **101** is defined to extend in parallel to the camshaft **34** from a portion of the cylinder head **22** closer to one end thereof in the axial direction of the camshaft **34** to a substantially central portion of the cylinder head **22** in the axial direction of the camshaft **34**, and the major portion of the second EGR passage **101** opens into the intake-side fastening face **35**. However, the major portion of the opening of the second EGR passage **101** into the intake-side fastening face **35** is closed by the gasket **45** interposed between the intake-side fastening face **35** and the plate **44**.

On the other hand, the protrusion **22***a* of the cylinder head **22** is provided with bosses **103** for mounting fuel injection valves **102** for injecting fuel into the intake ports **40**, and the second EGR passage **101** is disposed effectively in a space between the intake port **40** and the fuel injection valve **102** at a location corresponding to the first and second combustion chambers **29**A and **29**B in order to further contribute to the compactness of the cylinder head **22**.

The bosses **103** are provided at lower portions of the first insertion/removal guide sections **68** each having the arcuate cross-sectional shape with at least upper portion opened on the side opposite from the camshaft **34**, so that they adjoin one another in the direction along the axis of the camshaft **34**. If the fuel injection valves **102** and the first insertion/removal guide sections **68** are disposed as described above, the fuel injection valves **102** can be disposed in more proximity to the first spark plugs **66**, while avoiding the interference with the first insertion/removal guide sections **68**, thereby contributing to the compactness of the engine.

Moreover, the bosses **103** are provided at the protrusions **22***a* of the cylinder head **22** so as to be integrally connected at no distance to the first insertion/removal guide sections **68** and hence, the rigidity of the bosses **103** can be enhanced.

Further, the second insertion/removal guide sections **69**, the intake-side rocker arms **59**, the intake valves **47** and the bosses **103** are arranged substantially side by side in the same plane perpendicular to the axis of the camshaft **34**. Such disposition enables the further compactness of the cylinder head **22**.

The second EGR passage **101** extends in parallel to the axis of the camshaft **34** in the vicinity of the fuel injection valves **102** corresponding to the first and second combustion chambers **29**A and **29**B, and a portion of the boss **103** provided on the cylinder head **22** in order to mount the fuel injection valve **102** at a location corresponding to each of the first and second combustion chambers **29**A and **29**B intrudes as an intruding portion **103***a* into the second EGR passage **101**.

On the other hand, the cylinder head **22** is provided, for the purpose of reduction in weight, with a recess **108** which opens into the intake-side fastening face **35** on an extension of an inner end of the second EGR passage **101** and closed by the gasket **45**, and a portion of the boss **103** provided on the cylinder head **22** in order to mount the fuel injection valve **102** at a location corresponding to the third combustion chamber **29**C intrudes into the recess **108** as an intruding portion **103***b* in order to ensure a wall thickness.

Referring particularly carefully to FIG. **10**, a communication passage **104** is provided in the gasket **45** abutting against the intake-side fastening face **35** and leads to the inner end of the second EGR passage **101**. Provided in a surface, adjacent the gasket **45**, of the plate **44** interposing the gasket **45** between the surface and the intake-side fastening face **35** are a common groove **105** extending in both of leftward and rightward directions with its central portion leading to the communication passage **104**, and branch grooves **106**, **106** leading to opposite ends of the common groove **105**. One end of the common groove **105** is set at a location corresponding to between the intake ports **40**, **40** in the first and second combustion chambers **29**A and **29**B, and the other end of the common groove **105** is set at a location corresponding to between the intake ports **40**, **40** in the third and fourth combustion chambers **29**C and **29**D. One of the branch grooves **106** is defined to extend from the one end of the common groove **105** toward the intake ports

40, 40 in the first and second combustion chambers 29A and 29B, and the other branch groove 106 is defined to extend from the other end of the common groove 105 toward the intake ports 40, 40 in the third and fourth combustion chambers 29C and 29D.

Moreover, a portion of the common groove 105 excluding a portion corresponding to the communication passage 104 as well as major portions of the branch grooves 106, 106 are occluded by the gasket 45 interposed between the intake-side fastening face 35 and the plate 44, and passages 107 are provided in the gasket 45 to individually lead to the intake ports 40 so as to have notches 107*a* leading to tip ends of the branch grooves 106, 106 and connected to the passages 107. Notches 40*a* leading to the notches 107*a* are provided at ends of the intake ports 40 opening into the intake-side fastening face 35 so as to be connected to the intake ports 40.

Thus, the EGR gas guided from the exhaust port 41 in the first combustion chamber 29A via the communication bore 95, the first EGR passage 94, the inlet-side passage 96, the EGR valve 99, the outlet-side passage 98 and the communication bore 100 to the second EGR passage 101 is guided from the communication passage 104 in the gasket 45 to the common groove 105 and further diverted into the pair of branch grooves 106, 106 and dispensed from the notches 107*a* and 40*a* to the intake ports 40 in the combustion chambers 29A to 29D.

Spark plug chambers 109A, 109B, 109C and 109D are defined in the cylinder head 22 in correspondence to the combustion chambers 29A, 29B, 29C and 29D with a portion of each of the first spark plugs 66 exposed thereto, so as to be disposed partially at the protrusion 22*a* of the cylinder head 22 and open into the intake-side fastening face 35. Openings of the spark plug chambers 109A, 109B, 109C and 109D into the intake-side fastening face 35 are closed by the gasket 45. Moreover, spark plug chambers 109A and 109B are defined in the cylinder head 22 so as to be interposed between the combustion chambers 29A and 29B and the second EGR passage 101.

It should be noted here that the first spark plug 66 is mounted at the lower end of the first plug holder 73 inserted into the first insertion/removal guide section 68 with the sealing portion 73*a* resiliently brought into contact with the intermediate cylindrical portion 68*a* of the first insertion/removal guide section 68, but a complete sealing by the sealing portion 73*a* cannot be achieved, and it is difficult to avoid the entrance of water from between the sealing portion 73*a* and the cylindrical portion 68*a* into each of the spark plug chambers 109A, 109B, 109C and 109D.

Therefore, drainage bores 110A, 110B, 110C and 110D for draining the water entering into each of the spark plug chambers 109A, 109B, 109C and 109D are provided in the protrusion 22*a* of the cylinder head 22 in such a manner that one ends thereof open into lower ends of the spark plug chambers 109A, 109B, 109C and 109D and the other ends thereof open into the outer surface of the lower portion of the protrusion 22*a*.

A pouch hole-shaped fastening boss 111 for fastening the intake device 42 to the protrusion 22*a* by one of a plurality of fastening bolts 115 is provided on the cylinder head 22 at a location corresponding to the third combustion chamber 29C to intrude into a lower portion of the spark plug chamber 109C. Moreover, the position of the drainage bore 110C is determined, so that one end thereof opens into a lower portion of the spark plug chamber 109C between the spark plug 66 and the fastening boss 111 in the direction along the axis of the camshaft 34.

With the dispositions of the fastening boss 111 and the drainage bore 110C, it is possible to avoid an increase in size of the cylinder head 22. More specifically, when the fastening boss is disposed at a location offset from the spark plug chamber 109C, it is impossible to avoid an increase in size of the cylinder head, but the increase in size of the cylinder head can be avoided by provision of the fastening boss 111 intruding into the lower portion of the spark plug chamber 109C. Moreover, the water entering into the spark plug chamber 109C from around the first spark plug 66 can be guided to the drainage bore 110C, so as not to be obstructed by the fastening boss 111.

A fastening boss 112 for fastening the intake device 42 to the protrusion 22*a* is provided on the cylinder head 22 at a location corresponding to the first combustion chamber 29A to intrude into the lower portion of the spark plug chamber 109C. Moreover, one end of the drainage bore 110A opens into a lower portion of the spark plug chamber 109A at a location where the fastening boss 112 is interposed between the drainage bore 110A and the first spark plug 66 in the direction along the axis of the camshaft 34, and a guide wall 113 for guiding the water entering around the first spark plug 66 toward the drainage bore 110A is provided between an inner wall of the spark plug chamber 109A and the fastening boss 112.

Even with such dispositions of the fastening boss 112, the drainage bore 110C and the guide wall 113, the increase in size of the cylinder head 22 can be avoided, and the water entering into the spark plug chamber 109A from around the first spark plug 66 can be guided by the guide wall 113 toward the drainage bore 110A so as not to be obstructed by the fastening boss 112. In addition, the rigidity of the fastening boss 112 can be increased by the guide wall 113.

Further, the fastening boss 112 and the guide wall 113 are positioned at a lower portion of an inner surface of the spark plug chamber 109A on the side of the projecting end of the protrusion 22*a*, i.e., on the side of the intake-side fastening face 35 to form a flat surface 114 which is parallel to the camshaft 34, and a threaded bore 116 is provided between the intake-side fastening face 35 and the flat surface 114, so that a fastening bolt 115 is threadedly engaged into the threaded bore 116.

Therefore, the water entering into the spark plug chamber 109A from around the first spark plug 66 can be guided by the flat surface 114 toward the drainage bore 110A so as not to be obstructed by a fastening portion of the fastening bolt 115.

Referring also to FIGS. 12 and 13, a head-side water jacket 118 is provided in the cylinder head 22 to lead to a block- side water jacket 119 provided in the cylinder block 21, and a port 120 leading to the head-side water jacket 118 on the side of the axially other end of the camshaft 34 is connected to a heater core 122 through a line 121. A thermostat 126 is mounted in a mounting recess 134 (see FIG. 3) provided in the cylinder head 22 on the axially other end of the camshaft 34. The heater core 122 is connected to the thermostat 126 through a line 123, and the head-side water jacket 118 within the cylinder head 22 is also connected to the thermostat 126 through a bypass passage 133.

A line 125 is connected at one end to the port 120, and after warm water is supplied through an intermediate portion of the line 125 to an auxiliary such as a throttle body 124, the line 125 is connected to a line 136. The line 136 is connected at one end to a port 135 provided in the cylinder head 22 to lead to an outlet of the thermostat 126, and at the other end to a suction side of a water pump 131. A line 132 for guiding a portion of cooling water from the head-side

water jacket **118** in the cylinder head **22** is also connected to the suction side of the water pump **131**. A discharge side of the water pump **131** is connected to the head-side water jacket **118** in the cylinder head **22**.

A port **127** is provided in the cylinder head **22** to lead to the block-side water jacket **119** in the cylinder block **21**. The port **127** is connected to an inlet of a radiator **129** through a line **128**, and an outlet of the radiator **129** is connected to the thermostat **126** through a line **130**.

In such a cooling water circuit, the thermostat **126** disconnects the line **136** and the line **130** from each other and permits the line **123** and the bypass passage **133** to communicate with the line **136**, when the engine is cold, whereby the major portion of the cooling water supplied from the water pump **131** to the head-side water jacket **118** is fed to the heater core **122** and the auxiliary such as the throttle body **124**, as shown by a solid line arrow in FIG. **12**, but the cooling water cannot be supplied to the radiator **129**.

On the other hand, when the engine is hot, the thermostat **126** disconnects the bypass passage **133** and the line **130** from each other and permits the lines **123** and **130** to communicate with the line **136**, whereby the cooling water supplied from the water pump **131** to the head-side water jacket **118** is fed to the heater core **122** and the auxiliary such as the throttle body **124** and to the block-side water jacket **119**, as shown by a solid line arrow in FIG. **13**. The cooling water cooled by feeding thereof from the block-side water jacket **119** to the radiator **129** is drawn into the water pump **131**.

The operation of this embodiment will be described below. The single rocker shaft **55**, on which the intake-side rocker arm **59** moved following the intake-side cam **57** provided on the camshaft **34** to drive the intake valve **47** and the exhaust-side rocker arm **60** moved following the exhaust-side cam **58** provided on the camshaft **34** to drive the exhaust valve **48** are commonly carried, is fixedly disposed in the cylinder head **22** above the camshaft **34**. The first insertion/removal guide section **68** for guiding the insertion and removal of the first spark plug **66** and the intake valve **47** are disposed so as to be superposed one on another at least partially in the view of projection onto the plane perpendicular to the axis of the camshaft **34**, and the second insertion/removal guide section **69** for guiding the insertion and removal of the second spark plug **67** and the exhaust valve **48** are disposed so as to be superposed one on another at least partially in the view of projection onto the plane.

Therefore, the intake valve **47** and the first insertion/removal guide section **68** as well as the exhaust valve **48** and the second insertion/removal guide section **69** can be disposed at the locations closer to the camshaft **34**, and the width of the cylinder head **22** in the direction perpendicular to the axis of the camshaft **34** can be set at a small value, as compared with the conventional SOHC-type engine including a pair of rocker shafts.

The shortest distance L**2** in the projection view between at least one of the first and second insertion/removal guide sections **68** and **69** and the camshaft **34** is set smaller than the shortest distance L**1** in the projection view between at least one of the valve stems **47***a* and **48***a* of the intake valve **47** and the exhaust valve **48** and the camshaft **34**. Therefore, at least one of the first and second insertion/removal guide sections **68** and **69** can be disposed in more proximity to the camshaft **34**, whereby the width of the cylinder head in the direction perpendicular to the axis of the camshaft **34** can be set at a small value. In addition, by setting the shortest distance L**2** between the first and second insertion/removal guide sections **68** and **69** and the camshaft **34** smaller than the shortest distance L**1** between the valve stems **47***a* and **48***a* of the intake valve **47** and the exhaust valve **48** and the camshaft **34** as in the embodiment, both of the first and second insertion/removal guide sections **68** and **69** can be disposed in more proximity to the camshaft **34**, whereby the width of the cylinder head **22** in the direction perpendicular to the axis of the camshaft **34** can be set at a further small value.

Additionally, since the upper ends of the first and second insertion/removal guide sections **68** and **69** integral with the cylinder head **22** are formed in a curved manner to protrude into the valve-operating chamber **26**, the amount of protrusion of the upper ends of the first and second insertion/removal guide sections **68** and **69** from the side of the cylinder head **22** can be suppressed to a small level, thereby contributing to the compactness of the cylinder head **22** and enhancing the rigidity of the upper end of the sidewall of the cylinder head **22**. Moreover, the inclination of the first and second spark plugs **66** and **67** can be suppressed to a small level to enhance the ignitability.

Further, the boss **103** for mounting the fuel injection valve **102** for injecting the fuel into the intake port **40** is provided on the cylinder head **22**, and the second EGR passage **101** for guiding the EGR gas is provided in the cylinder head **22** to extend in parallel to the axis of the camshaft **34** in the vicinity of the fuel injection valve **102** with a portion of the boss **103** intruding into the EGR passage **101**. Therefore, the second EGR passage **101** can be provided in the cylinder head **22** in the vicinity of the fuel injection valve **102**, while ensuring the wall thickness of the boss **103** on the side of the second EGR passage **101**. The second EGR passage **101** can be disposed in the vicinity of the fuel injection valve **102**, while ensuring the rigidity of the boss **103** and inhibiting an adverse affection due to the high-temperature EGR gas flowing through the second EGR passage **101** from being exerted to the fuel injection valve **102**, thereby achieving the compactness of the cylinder head **22**.

The position PI of the central portion of the upstream end of the intake port **40** provided in the cylinder head **22** and the position PO of the central portion of the downstream end of the exhaust port **41** are determined to coincide with each other in the direction along the axis of the camshaft **34** and hence, the distance between the cylinders of the multi-cylinder engine can be set to be short, and the size of the cylinder head **22** in the direction along the axis of the camshaft **34** can be reduced.

Further, the cylinder head **22** is integrally provided with the protrusion **22***a* projecting outwards from the cylinder block **21**, and the spark plug chambers **109**A, **109**B, **109**C and **109**D corresponding to the combustion chambers **29**A, **29**B, **29**C and **29**D with a portion of each of the first spark plugs **66** facing the corresponding combustion chamber are defined in the cylinder head **22** in such a manner that a portion of each of the spark plug chambers is disposed in the protrusion **22***a*. Therefore, the volume of each of the spark plug chambers **109**A to **109**D can be set at relatively large value to provide a reduction in weight of the cylinder head **22**.

Moreover, the cylinder head **22** is provided with the drainage bores **110**A, **110**B, **110**C and **110**D, one end of each of which opens into the lower portion of each of the spark plug chambers **109**A, **109**B, **109**C and **109**D and the other end of each of which opens into the outer surface of the lower portion of the protrusion **22***a*, i.e., the outer surface of the lower portion of the cylinder head **22** outside the cylinder head **21**. Therefore, the water entering into the spark plug

chambers **109**A to **109**D can be reliably discharged through the drainage bores **110**A to **110**D shortened in length and simplified.

Although the embodiment of the present invention has been described, it will be understood that the present invention is not limited to the above-described embodiment, and various modifications in design may be made without departing from the scope of the invention defined in claims.

What is claimed is:

1. An SOHC-type engine comprising first and second insertion/removal guide sections **(68, 69)** for guiding the insertion and removal of first and second spark plugs **(66, 67)**, respectively, provided on a cylinder head **(22)** including an intake valve **(47)** and a first spark plug **(67)** disposed therein and arranged along an axis of a camshaft **(34)**, and an exhaust valve **(48)** and a second spark plug **(67)** disposed therein and arranged along the axis of said camshaft **(34)**, wherein a single rocker shaft **(55)** is disposed above said camshaft **(34)**; and

an intake-side rocker arm **(59)** pivotally following an intake-side cam **(57)** provided on said camshaft **(34)** to drive the intake valve **(47)** and an exhaust-side rocker arm **(60)** pivotally following an exhaust-side cam **(58)** provided on said camshaft **(34)** to drive the exhaust valve **(48)** carried commonly on said rocker shaft **(55)**,

wherein said first insertion/removal guide section **(68)** and the intake valve **(47)** are disposed so as to be superposed one on another at least partially in a view of projection onto a plane perpendicular to the axis of said camshaft **(34)**, and said second insertion/removal guide section **(69)** and the exhaust valve **(48)** are disposed so as to be superposed one on another at least partially in a view of projection onto said plane.

2. An SOHC-type engine according to claim **1**, wherein the shortest distance in said projection view between at least one of said first and second insertion/removal guide sections **(68, 69)** and said camshaft **(34)** is set smaller than the shortest distance in said projection view between at least one of valve stems **(47***a*, **48***a*) of said intake and exhaust valves **(47, 48)** and said camshaft **(34)**.

3. An SOHC-type engine according to claim **1**, wherein the shortest distance in said projection view between said first insertion/removal guide section **(68)** and said camshaft **(34)** is set smaller than the shortest distance in said projection view between a valve stem **(47***a*) of the intake valve **(47)** and said camshaft **(34)**, and the shortest distance in said projection view between said second insertion/removal guide section **(69)** and said camshaft **(34)** is set smaller than the shortest distance in said projection view between a valve stem **(48***a*) of the exhaust valve **(48)** and said camshaft **(34)**.

4. An SOHC-type engine according to any of claims **1** to **3**, wherein at least one of upper ends of said first and second insertion/removal guide sections **(68, 69)** is formed in a curved manner to protrude into a valve-operating chamber **(26)** defined between said cylinder head **(22)** and a head cover **(23)** coupled to said cylinder head **(22)**.

5. An SOHC-type engine according to any of claims **1** to **3**, wherein at least an upper portion of said first insertion/removal guide section **(68)** is formed to have an arcuate cross-sectional shape opened in a direction opposite from said camshaft **(34)**.

6. An SOHC-type engine according to any of claims **1** to **3**, wherein at least one of said first and second insertion/removal guide sections **(68, 69)** is disposed at least partially between each of head bolts **(70)** for fastening said cylinder head **(22)** to a cylinder block **(21)** at locations spaced apart from one another along the axis of said camshaft **(34)** and at least one of said intake and exhaust valves **(47, 48)**.

7. An SOHC-type engine according to any of claims **1** to **3**, wherein at least one of said first and second insertion/removal guide sections **(68, 69)** is disposed at least partially between a shaft bearing portion **(32)** provided on said cylinder head **(22)** to carry said camshaft **(34)** thereon for rotation and at least one of said intake and exhaust valves **(47, 48)**.

8. An SOHC-type engine according to any of claims **1** to **3**, wherein said first and second insertion/removal guide sections **(68, 69)** are formed to protrude toward said valve-operating chamber **(26)** at locations corresponding to contact potions of said intake-side and exhaust-side cams **(57, 58)** immersed partially in an oil bath **(71)** defined on said cylinder head **(22)** with said intake-side and exhaust-side rocker arms **(59, 60)**.

9. An SOHC-type engine according to claim **1**, wherein at least an upper end of said second insertion/removal guide section **(69)** is formed into a cylindrical shape, and bolts **(82)** for fastening a head cover **(23)** to said cylinder head **(22)** are disposed between said second insertion/removal guide sections **(69)** individually corresponding to a plurality of combustion chambers **(29**A, **29**B, **29**C and **29**D).

10. An SOHC-type engine according to claim **1**, wherein a first plug holder **(73)** connected to the first spark plug **(66)** inserted into said first insertion/removal guide section **(68)** protrude from said cylinder head **(22)**; an ignition coil **(76)** connected to an upper end of said first plug holder **(73)** are fastened to a head cover **(23)** coupled to said cylinder head **(22)** by a single coil bolt **(77)**; and a detent portion **(78)** are integrally provided on said head cover **(23)** to come into contact with the upper end of said first plug holder **(73)** in order to receive a load around the axis of said coil bolt **(77)** acting on a protrusion of said first plug holder **(73)** from said cylinder head **(22)** during tightening of said coil bolt **(77)**.

11. An SOHC-type engine according to claim **10**, wherein bolts **(82)** for fastening said head cover **(23)** to said cylinder head **(22)** are disposed between said detent portions **(78)** corresponding individually to a plurality of combustion chambers **(29**A to **29**D).

12. An SOHC-type engine according to claim **10** or **11**, wherein each of said detent portions **(78)** is formed into a ring shape.

13. An SOHC-type engine according to any of claim **10** or **11**, wherein a fastening boss **(93)** for fastening said ignition coil **(76)** is provided on said head cover **(23)** inside said detent portion **(78)**.

14. An SOHC-type engine according to any of claim **10** or **11**, wherein a resilient member **(92)** is mounted between said detent portion **(78)** and said first plug holder **(73)**.

15. An SOHC-type engine according to claim **1**, wherein upper end faces of said first and second insertion/removal guide sections **(68, 69)** are formed in the same plane, and a head cover **(23)** is coupled to said upper end faces of the first and second insertion/removal guide sections **(68, 69)**.

16. An SOHC-type engine according to claim **1**, wherein an upper portion of said first insertion/removal guide section **(68)**, into which said first plug holder **(73)** connected to said first spark plug **(66)** is inserted, is formed to have an arcuate cross-sectional shape opened forwards in a direction **(31)** of forward movement of the vehicle.

17. An SOHC-type engine according to claim 1, wherein an upper portion of each of said first insertion/removal guide section (68) is formed to have an arcuate cross-sectional shape opened in direction opposite from said camshaft (34), and a boss (103) for mounting a fuel injection valve (102) is provided on said cylinder head (22) at a location adjoining a lower portion of said first insertion/removal guide section (68) in a direction along the axis of said camshaft (34).

18. An SOHC-type engine according to claim 1, wherein a boss (103) for mounting a fuel injection valve (102) is provided on the cylinder head (22) so as to be integrally connected to said first insertion/removal guide sections (68).

19. An SOHC-type engine according to claim 1, wherein said second insertion/removal guide section (69), an intake-side rocker arm (59), said intake valve (47) and a boss (103) provided on said cylinder head (22) to mount a fuel injection valve (102) are disposed substantially side by side on the same plane perpendicular to the axis of said camshaft (34).

20. An SOHC-type engine according to claim 1, wherein a protrusion (22*a*) is integrally provided on said cylinder head (22) to project outwards and sideways from a cylinder block (21); a spark plug chamber (109A, 109B, 109C, 109D) faced by a portion of said first spark plug (66) is defined in the cylinder head (22) in such a manner that a portion of said spark plug chamber is disposed on said protrusion (22*a*); and a drainage bore (110A, HOB, HOC, HOD) is provided in said protrusion (22*a*), so that one end thereof opens into a lower portion of said spark plug chamber (109A to 109D) and the other end thereof opens into an outer surface of a lower portion of said protrusion (22*a*).

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